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AUTOBALANCE
COMPONENT BRIDGE
B421
MAINTENANCE MANUAL

WAYNE KERR

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MAINTENANCE MANUAL

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INTRODUCTION

The physical description, specification and use of this bridge are dealt with in the Operating Instructions supplied with the instrument. This manual has been prepared for the benefit of those users who require a more detailed knowledge of the circuits used, their operation and adjustment.

The first section is a functional description of the complete instrument. This gives a brief summary of the basic bridge system and is followed by a detailed description of the bridge for each facility (i. e., inductance, capacitance etc.). This section is adequately illustrated by means of block and schematic diagrams.

The second section gives a detailed description of the individual units contained in the instrument. Well-known circuits are not described in detail since such circuits are analysed in most standard text books on electronics. The illustrations appertaining to this section are, in general, the full circuit diagrams for the instrument; these are bound at the end of the manual.

The third section contains complete instructions for the adjustment of preset controls and the general checking of the instrument to ensure maximum efficiency of operation; tables of typical voltages are given. In preparing these instructions the use of any special test equipment has been avoided.

Finally, a complete list of electronic components is given.

FUNCTIONAL DESCRIPTION

1. The Autobalance Component Bridge B421 uses the transformer ratio-arm principle. A complete analysis of this type of bridge is given in the Wayne Kerr Monograph No. 1, 'The Transformer Ratio-Arm Bridge'. An analysis of the self-balancing principles used in this instrument is given in Electronic Engineering Vol. 35, No. 430, December 1963, 'Self-Balancing Transformer Ratio-Arm Bridges'. Copies of the Monograph and reprints of the article are available on request.

Basic Bridge System

2. The instrument comprises a transformer ratio-arm bridge fed from a 1000Hz oscillator, an error amplifier, a meter amplifier and phase-sensitive detector, a unity-gain amplifier and a guard amplifier.

3. In the inductance, capacitance and resistance facilities, a standard voltage is applied to the component under test. The resulting current is applied via a current transformer to the error amplifier, whose output is fed back to oppose the original current. Ideally, the system would balance when these currents were exactly equal. However, since this would remove the error amplifier input signal, the balance falls short of the ideal condition by an amount which can be predetermined according to the required accuracy of the bridge. The approach to the ideal condition is governed only by the gain of the error amplifier, which can be made as large as necessary. The method of application of the feedback and the evaluation of the result differs slightly in each facility but it will be shown that in each case the error amplifier output is proportional to the value of the component under test (or, with the decade in circuit, it is proportional to the difference between the decade setting and the value of the component under test).

4. The output from the error amplifier is then fed via the meter amplifier to the phase-sensitive detector. This detector takes its reference signal from the 1000Hz oscillator and the circuit is so arranged that only the in-phase component of the error amplifier output signal is fed to the meter. Operation of the minor term button introduces other phase-change networks so that the quadrature component is indicated on the meter.

5. The unity-gain amplifier is used only in the inductance, resistance and comparator facilities and its purpose is explained in the section dealing with the resistance bridge. When measuring high values of resistance, phase errors arising from stray capacitance between the I terminal and neutral are minimised by means of the guard amplifier.

Capacitance Bridge

6. Fig. 1 shows the basic bridge when switched for Capacitance and parallel resistance measurements. The voltage transformer* feeds a voltage E_u to the unknown capacitor C_u. The amplitude of this voltage‡ is selected by means of the Range Switch and is constant for the chosen range. The resultant current I_u through the capacitor under test is fed via the Range Switch to the current transformer T3. During the first stage of the measurement, the Decade switch is out of circuit and so the decade voltage E_s is zero and no current flows through the standard capacitor C_s. Thus, the only

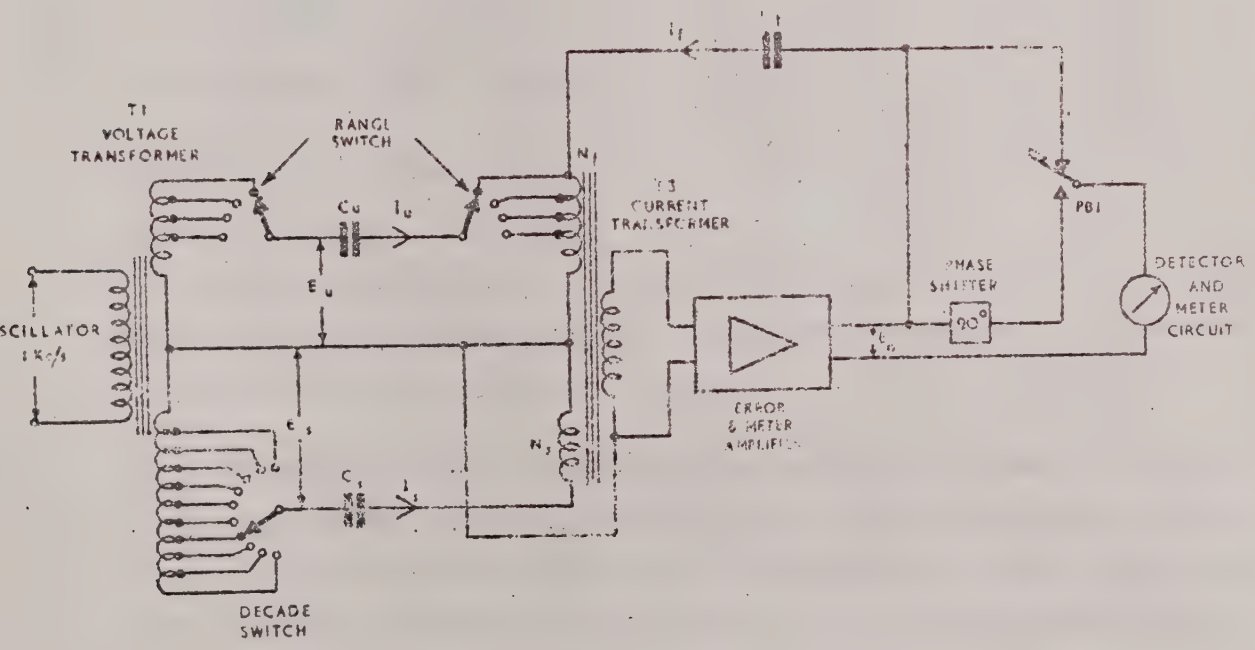

FIG. 1 CAPACITANCE BRIDGE - SCHEMATIC

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* For practical reasons, the voltage transformer is, in reality, two transformers T1 and T2. However, for the purpose of this part of the explanation they can be regarded as one.

‡ See also Appendix II.

input to the current transformer is that arising from C_u, the unknown capacitor. This input causes an error signal to be fed to the Error Amplifier, whose output E_o is applied to a feedback capacitor Cf (C57 on the Standards Board). The phases are so arranged that the resultant feedback current I_f opposes I_u in the current transformer. The effect of the residual flux can be assumed negligible owing to the high gain of the error amplifier (see para. 3).

Making this assumption then, if I_u flows in N_u turns (where N_u is that portion of N_f selected by the Range switch) and I_f in N_f turns:

$$I_u . N_u = I_f . N_f$$

But from Ohm's Law, again assuming the input voltage at T3 to be negligible compared with E_u and E_o:

$$I_u = j\omega C_u . E_u$$

$$\text{and } I_f = j\omega C_f . E_o$$

$$\text{therefore } j\omega C_u E_u N_u = j\omega C_f E_o N_f$$

$$\text{from which } C_u = E_o \cdot \frac{C_f N_f}{E_u N_u}$$

Thus the output from the error amplifier is directly proportional to the unknown capacitance, and in phase with E_u if C_u is pure. The meter can therefore be arranged to indicate capacitance directly.

7. To obtain greater discrimination and accuracy the standard capacitance C_s is switched into circuit by means of the Decade switch, and the first digit of the unknown can thus be backed off. At the same time, the feedback capacitor C_f is switched to a lower tap on the winding N_f so as to increase the meter sensitivity by a factor of ten**.

** When the Decade switch is set to OUT, C_f (terminal G on the Standards Board) is connected to the 100T tap on T3 (see fig. 13). On all other positions of the Decade switch, C_f is connected in series with C63 (whose value is approximately 50 times that of C_f) to the 10T tap on T3. C63 is included to adjust the feedback when the decade is in use. Capacitor C67 is connected to a single turn (wound in the negative sense) on the current transformer T3 so as to cancel the standing capacitance at the Unknown terminals.

Under these conditions:

$$Iu.Nu = If.Nf' + Is.Ns$$

where N_s is the number of turns on the current transformer connected to C_s; N_f' is the feedback winding in circuit. But as before:

$$I_u = j\omega C_u . E_u$$

$$I_f = j\omega C_f . E_o$$

$$\text{and } I_s = j\omega C_s . E_s$$

therefore $j\omega C_u . E_u . N_u = j\omega C_f . E_o . N_f' + j\omega C_s . E_s . N_s$

from which $$C_u = E_o . \frac{C_f . N_u}{E_u . N_f'} + E_s . \frac{C_s . N_s}{E_u . N_u}$$

Thus the first digit of the unknown is now given by E_s (The Decade), the remaining digits being given by E_o (The Meter).

8. It was stated earlier that the error amplifier output is directly proportional to the unknown capacitance, and in phase with E_u if C_u is pure. This signal is fed to the meter amplifier, in which a 180° (nominal) phase change takes place. Thus the meter amplifier output is in phase with the reference signal (which is in antiphase with E_u, being derived from opposite windings on T1) and is applied to the phase-sensitive detector to produce a direct indication on the meter. However, since the accuracy of the bridge is dependent upon the accuracy of the phase reversal in the meter amplifier, the correction network shown in Fig. 2a is connected across the amplifier for capacitance measurements.

9. When the 'minor term' button is operated, the error amplifier output is fed to the meter amplifier via a 90° phase-shift network. Any parallel conductance term present in the error amplifier input will thus produce an input to the meter amplifier which is in phase with E_u. This input is linear in terms of unknown parallel conductance, but the meter is provided with a reciprocal scale and so indicates parallel resistance. The phase-shift network is connected as a differentiator (see Fig 2b) so as to make the overall system aperiodic.

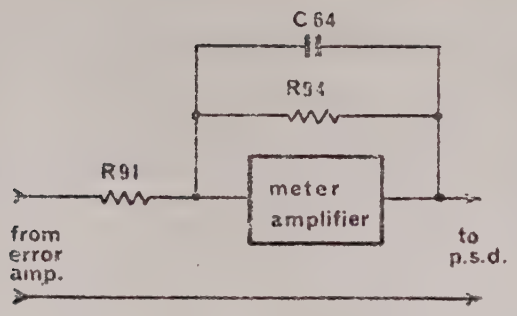


Fig. 2a Phase Correction Network
(C Measurement)

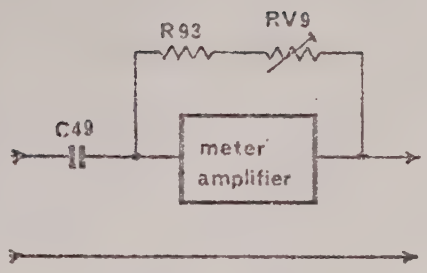


Fig. 2b 90° Phase-Shift Network
(R_p Measurement)

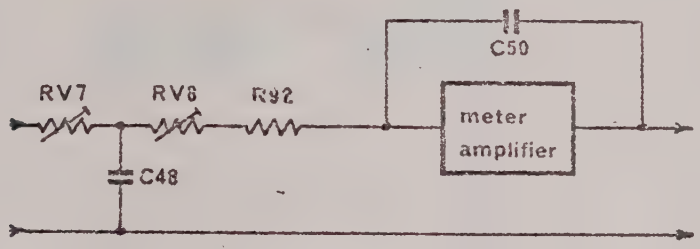


Fig. 2c 90° Phase-Shift Network (L Measurement)

10. The meter is scaled for parallel resistance measurements assuming the decade to be in use. Without the decade in use, the meter sensitivity is reduced by a factor of 10 and, consequently, Rp readings should be divided by 10.

Figure 13 shows all the bridge interconnections when the Facility switch is set to C.

Resistance Bridge

11. Fig. 3 shows the basic bridge when switched for resistance or inductance measurements. A standard winding on the voltage transformer T1 feeds a voltage E_s to a resistance standard R_s (R98 and R108); this causes a current I_s to flow through N_s turns of the current transformer. The signal generated in T3 secondary is fed to the error amplifier whose output E_o is fed back via the voltage transformer decade winding and the Decade switch to a unity-gain amplifier. The purpose of this amplifier is to isolate the low impedance winding of transformer T2 from the decade winding of T1. The output from the unity-gain amplifier is fed via the voltage transformer T2 and the Range switch to the unknown resistance. The current, I_u, flowing through the unknown resistance, is fed via the range switch to N_u turns of the current

transformer T3. The sense of this current is such that it opposes the 'standard' current I_s. As in the capacitance case, the residual flux in

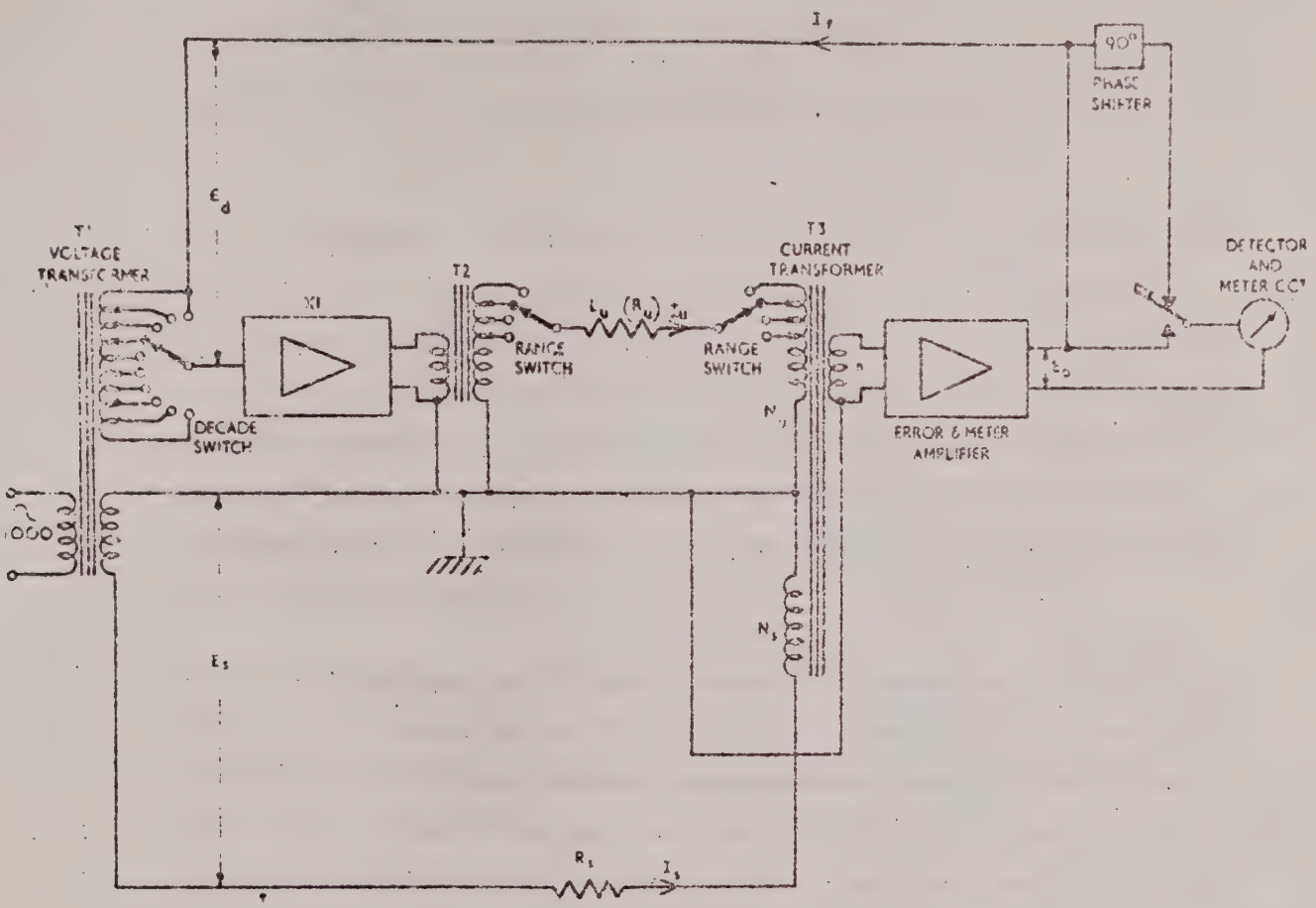


FIG. 3 INDUCTANCE AND RESISTANCE BRIDGE-SCHEMATIC

the current transformer is made sufficiently small to be neglected. It can be shown that

$$R_u = E_o \cdot \frac{R_s \cdot N_u}{E_s \cdot N_s}$$

from which it can be seen that the error amplifier output E_o is directly proportional to the Unknown resistance R_u, and in phase with E_s.

12. For greater discrimination and accuracy, the decade voltage E_d is introduced in series with E_o; at the same time N_s is switched so as to increase the meter sensitivity by a factor of ten. Under these conditions, it can be shown that

$$R_u = (E_d + E_o) \cdot \frac{R_s \cdot N_u}{E_s \cdot N_s'}$$

where N_s' is the new current transformer standard winding.

The first significant figure of the unknown is now given by the Decade setting and the subsequent figures by the meter indication.

Figure 14 shows all the bridge interconnections when the Facility switch is set to R.

13. The purpose of the resistors R55 - R60 and R109 is to preserve the stability of the feedback loop when the Unknown terminals are short circuited. This is done by introducing resistance on the 'current' side of the bridge and subtracting an equivalent voltage from the 'voltage' side. The value of the resistance introduced to the 'current' side of the bridge is determined by the minimum value required to maintain stability on the lowest range; this value (together with lead and switch contact resistance) is then multiplied by ten for each successive range.

14. The compensating voltage which is to be subtracted from the 'voltage' side of the bridge is derived from a two-turn winding on T1 wound in opposition to the decade winding; the decade and compensation voltages are connected in series in the feedback line from the error amplifier. Since the range switching on the 'voltage' side of the bridge is accomplished at the secondary of T2, it is necessary to provide only two values of compensating voltage. The ratio of these values is 10:1 and this caters for the ten-times change in meter sensitivity when the Decade is switched in and out. R95 and R96 perform the voltage division.

Inductance Bridge

15. The operation of the bridge for the measurement of inductance is similar to that for resistance measurement except that the Decade control is inoperative. The error amplifier output, E_o, is taken to the metering circuit by way of the 90^o phase shift network (fig. 2c). The meter therefore indicates that part of E_o which is in quadrature with the standard voltage E_s (i. e. the meter indicates inductance). When the minor term switch is operated, the metering circuit bypasses the phase shift network so that the meter then indicates the in-phase component of E_o (i. e.: it indicates the series resistance). In the inductance

mode, the phase-shift network is connected as an integrator to make the overall system aperiodic.

16. Let the unknown consist of R_u and L_u in series,

then $$I_u = \frac{E_o}{R_u + j\omega L_u} \quad \text{and} \quad I_s = \frac{E_s}{R_s}$$

since $$Iu.Nu = Is.Ns$$

therefore $$\frac{Eo.Nu}{Ru + j\omega Lu} = \frac{Es.Ns}{Rs}$$

$$Ru + j\omega Lu = Eo.\frac{Rs.Nu}{Es.Ns}$$

Let Eo be regarded as having real and imaginary parts.

$$Eo = (a + jb)$$

then $$Ru = \frac{a\,Eo.Rs.Nu}{Es.Ns}$$

and $$Lu = \frac{b\,Eo.Rs.Nu}{Es.Ns.}$$

Thus the series components are measured directly, in turn, by the metering circuit.

Figure 15 shows all the bridge interconnections when the Facility switch is set to L.

Electrolytic Capacitance and Leakage Current

17. The measurement of electrolytics above, say, 10μF becomes ever more difficult as the frequency increases because the impedance then tends towards a pure resistance. Thus, for example, at 1kHz the series resistance of such a capacitor may well be the major term. This instrument therefore measures high value capacitors by injecting a known direct current for a known time; the voltage developed across the capacitor then being measured by the meter circuit, in this case connected as a high impedance voltmeter.

If the standard current is Is and the time is t, then the charge

$$q = Eo.Cu.$$

so that $$Cu = \frac{Is.t}{Eo}$$

The meter indication is inversely proportional to the unknown capacitance so the reciprocal scale is used. A block diagram of the method is given

in fig. 4.

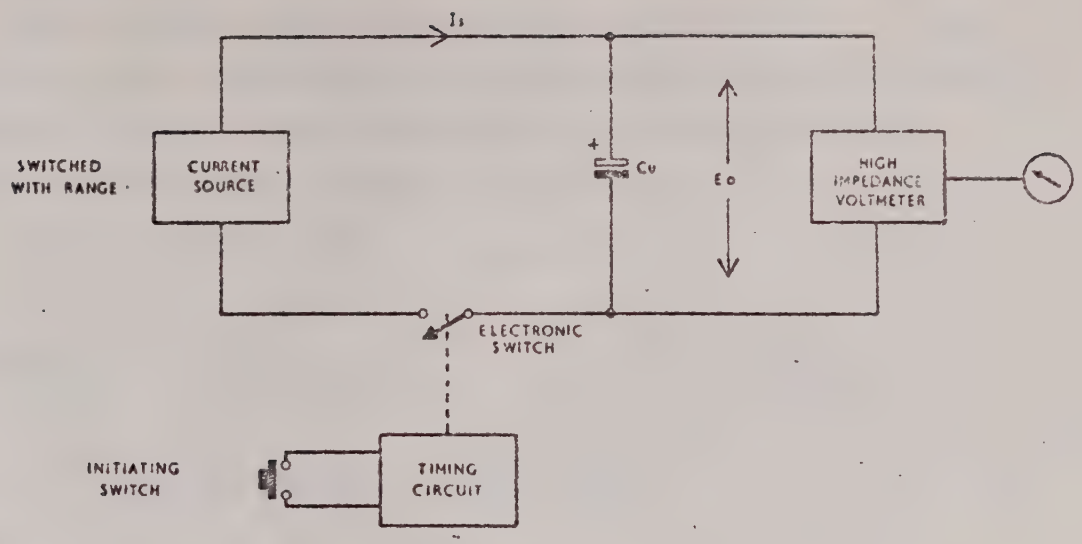


FIG. 4 ELECTROLYTIC CAPACITANCE MEASUREMENT — BLOCK DIAGRAM

18. Leakage current is measured by applying approximately 3V d. c. to the capacitor under test in series with the meter. The meter is short-circuited during the charging time to protect it from the high initial surge current. Meter shunts are provided to give three ranges of leakage current measuremen Figure 16 shows all the bridge interconnections when the Facility switch is set to Ce.

Comparator Bridge

19. The elements of the comparator bridge are arranged as shown in the schematic diagram fig. 5. It will be seen that the system is similar to that

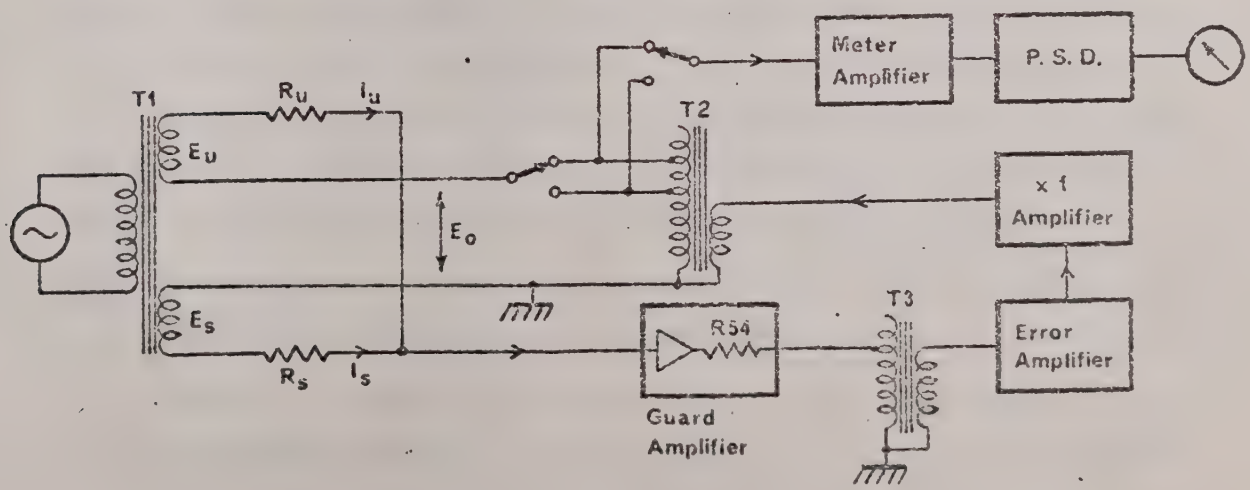


Fig. 5 Comparator Bridge — Schematic

of the resistance bridge (fig. 3) except that Eu takes the place of Ed and the error amplifier output is metered after transformation in T2. The system, in effect, algebraically adds to Eu a voltage Eo whose amplitude is adjusted by the feedback system so as to balance the bridge. Assuming sufficiently high gain, Iu = Is at balance.

$$I_u = \frac{E_u + E_o}{R_u} \quad \text{and} \quad I_s = \frac{E_s}{R_s}$$

therefore $$R_u = \frac{E_u + E_o}{E_s} \cdot R_s$$

Let $$R_u = (1 + \delta) R_s \text{ and } E_u = E_s$$

then $$(1 + \delta) = 1 + \frac{E_o}{E_s}$$

$$\delta = \frac{E_o}{E_s}$$

and so the meter can be scaled to give a direct indication of the percentage difference δ between R_u and R_s. To give the centre-zero scale, E_u is increased by an amount representing one-half f. s. d. of the metering circuit.

20. Since both R_u and R_s are connected externally and their values, it is assumed, will always be within ±25% of each other, it is not necessary to switch the voltage and current transformer windings. The error signal at the junction of R_u and R_s is, for a given percentage difference, independent of their absolute impedance provided that the junction is not significantly loaded. The high input impedance of the guard amplifier prevents the loading of the junction by the current transformer T3. The guard amplifier gives a x 1 voltage gain and the error signal is then converted by R54 into a current input to T3. The voltage transformer T2 is switched so as not to impose too heavy a load on the x 1 amplifier when comparing low value impedances.

NOTE The comparator compares impedances so that, when comparing capacitors, the standard and unknown component connections must be interchanged.

Example. Comparing a standard 10kΩ with an 11.2kΩ 'unknown' gives an indication of +12%. Comparing a standard 10μF capacitor with an

11.2μF 'unknown' would give an indication of -10.7% because the impedance of the 11.2μF capacitor is 0.893 of the impedance of the 10μF capacitor. Reversing the connections gives the correct result of +12%.

Figure 17 shows all the bridge interconnections when the facility switch is set to %A or %B.

Guard System

21. The necessity for the introduction of compensating resistance to the 'current' side of the bridge was explained in para. 13. On the higher resistance ranges, this added resistance, in conjunction with the unknown resistance and the capacitance of the I terminal screened lead, is sufficiently large to form an inductive circuit, that is to say, the network behaves as though it were an inductance. Thus the bridge cannot give an accurate indication of the unknown resistance unless the stray capacitance is neutralized. The effective circuit is shown in Fig. 6a.

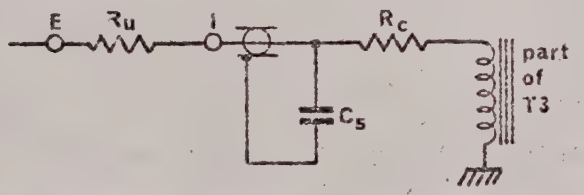


Fig. 6a Effective I- Terminal Circuit on L & R Functions

R_u = Unknown resistance

R_c = Compensating resistance

C_s = Stray capacitance of I-terminal lead

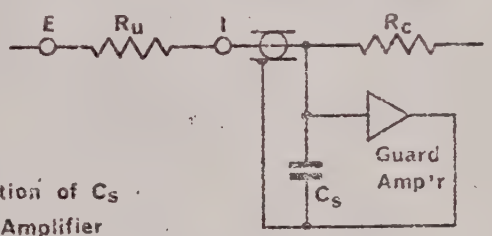


Fig. 6b Neutralization of C_s by Guard Amplifier

22. Suppose, now, that a unity-gain amplifier is connected across Cs as shown in Fig. 6b. Any change in voltage at the upper end of Cs will now be accompanied by an equal change at the lower end, so that Cs is prevented from taking current and is thus effectively neutralized. It follows that the guard amplifier must have a very high input impedance and that its input capacitance must be small compared with Cs.

Calibration

23. (a) F.S.D. (L.C.R.) When the Calibrate switch is set to this position, a 10T winding on the voltage transformer T1 is connected to the meter amplifier via switches S2/3B, S4/B and terminals K/B on the standards

board. This provides a voltage which is in phase with the phase-sensitive detector reference voltage and is exactly correct for a full-scale deflection of the meter. The potentiometer RV11 (f. s. d. - L. C. R.) is adjusted until the meter indicates full scale. Note that when the Facility switch is set to C, switch S2/3B selects a 10T winding in phase opposition; this is becase the meter polarity is reversed in the capacitance bridge.

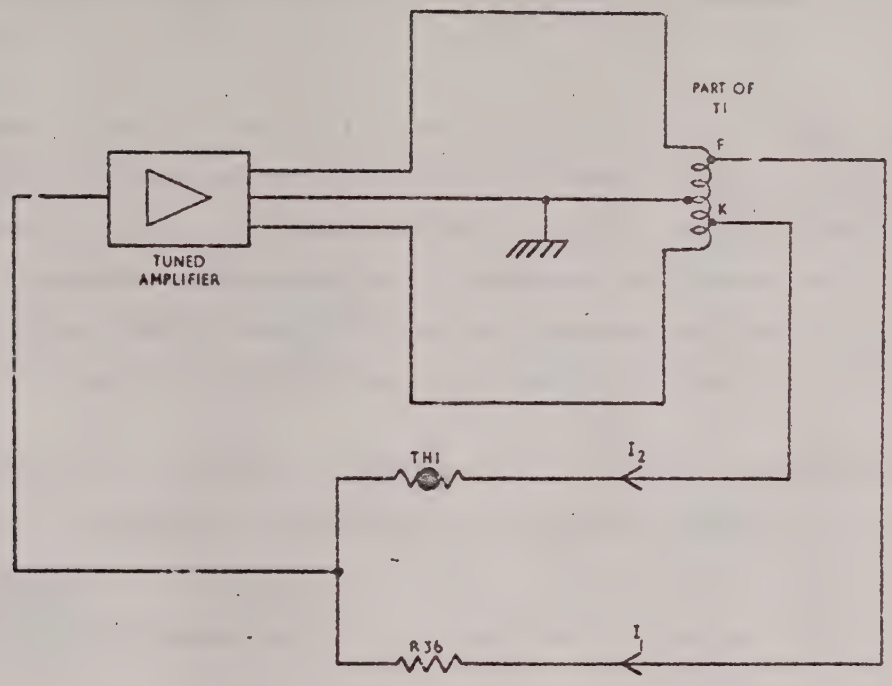
(b) Set Zero (C_e) On this facility, the meter is shunted by R18 in series with RV10. RV10 is adjusted until the meter indicates infinity on the reciprocal scale.

CIRCUIT DESCRIPTION

24. This section describes the operation of the bridge oscillator, the phase-sensitive detector, the various amplifiers and the high capacitance measurement unit. The standards Board (fig. 23) contains all but one of the bridge standards and also the phase-shift components; it requires no further description.

Oscillator

25. The oscillator comprises a tuned high-gain amplifier which is made to oscillate by the application of positive feedback via R36. Negative feedback is also applied to the amplifier to control the level of oscillation. The negative feedback path incorporates a thermistor, TH1, so that the oscillator output is virtually unaffected by variations of load, supply voltages or ambient temperature. Fig. 7 is a schematic diagram of the oscillator showing the feedback connections to the voltage transformer T1. At low signal levels the resistance of TH1 is high and therefore the current I_2 is low. As the signal level increases the resistance of TH1 falls and I_2 increases. The loop gain of the system is made sufficiently high, and the thermistor bridge winding symmetrical so that the system stabilises at a level at which I_1 and I_2 are very nearly equal. At this point, the resistance of TH1 is approximately equal to that of R36. Note that the printed circuit board arbitrarily called the 'oscillator' contains only that part of the oscillator which is, more strictly, the tuned amplifier; the transformer T1 and the thermistor form part of the interconnections (see Fig. 12).



FIC. 7 BRIDGE OSCILLATOR
SCHEMATIC

26. Referring to the circuit diagram Fig. 18, the tuned amplifier comprises the transistors VT11 to VT14 inclusive. VT11 and VT12, which form the high-gain amplifier, are connected as a d. c. feedback pair to give improved stability over the operating temperature range. Initially, the collector of VT11 and the base of VT12 are at the supply potential and so VT12 conducts. The potential at the emitter of VT12 approaches that of the supply and this potential is divided by the potentiometer R30, R31 and R32. The potential at the junction of R30 and R31 is fed back via R25 to the base of VT11, so causing VT11 to conduct. VT12 base and, hence, emitter potentials are reduced and this, in turn, reduces the potential at VT11 base. The system is stabilised at a level determined by the feedback tapping point on VT12 emitter. The emitter circuit of VT11 is left un-bypassed and the resulting current feedback helps to stabilise the operating conditions. The d. c. feedback to VT11 base greatly reduces the tendency of the base/emitter potential to drift with temperature variation; this ensures that the operating point for VT12 collector is reasonably constant. VT12 emitter is decoupled by C6 to prevent feedback at the operating frequency. The collector load for VT11 is R27 shunted by the phase correcting network R28/C4; that for

VT12 is the tuned circuit comprising C5 and the primary of L1. This circuit is tuned to 1kHz and determines the operating frequency of the oscillator.

27. Transistors VT13 and VT14 form a push-pull class B output stage. A small forward bias, obtained from VT12 emitter circuit, is applied to the transistors to reduce crossover distortion. R34 and R35 protect the output transistors from damage which would otherwise occur owing to direct currents flowing through the low d. c. resistance of the transformer winding. C9 and C10 provide a low impedance signal path to the transformer.

28. Transistors VT9 and VT10 form a full-wave phase sensitive detector whose reference signal is derived from the oscillator output. It will be

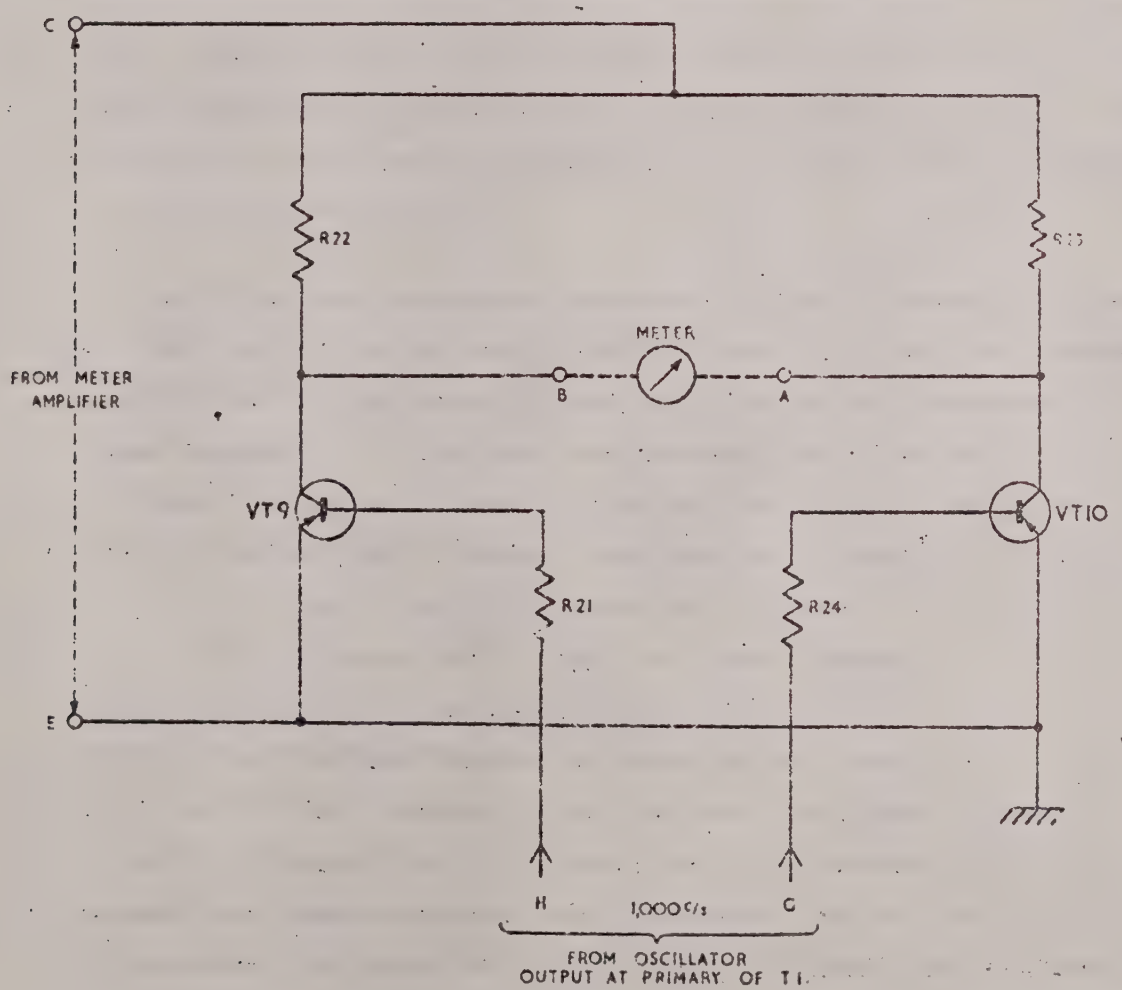


FIG. 8 PHASE-SENSITIVE DETECTOR SCHEMATIC

seen from Fig. 8 that only when the signals from the meter amplifier are in phase with the reference signal will the meter indication be in the correct sense.

Error Amplifier

29. The function of the error amplifier is to amplify the signal resulting from the net flux produced in the current transformer, T3, by the standard, unknown and feedback currents (I_s, I_u and I_f in fig. 1 and 3). As mentioned in para. 3, the accuracy of the bridge is in direct proportion to the smallness of this signal, and since it is the error amplifier output that is indicated on the meter, it follows that high gain, together with freedom from distortion, are essential qualities required in this amplifier.

30. The error amplifier comprises the two d. c. feedback pairs VT22/VT24 and VT26/VT27-VT28, and a peak detector VT29 which, together with VT23 and VT25, forms an automatic gain control circuit. These are shown in simplified form in Fig. 9.

31. The general principle of operation of the d. c. feedback amplifiers is the same as that already described in para. 26. The error amplifier input is fed in at terminal TX and passes via the input resistors R62/R61 and capacitor C26 to the first d. c. feedback pair at the base of VT22. R62/R61 form part of the a. g. c. system, which is described at the end of this sub-section. Feedback from collector to base of VT22 is selected for the L, C and R facilities as follows:

(a) through C29 and R66 for inductance measurement,

(b) through C28 for capacitance measurements,

(c) through C29 and R65 for resistance measurements;

this is necessary because the gain and phase shift required differ for each facility. The networks comprising C24, C58/R100 and C59/R102 are phase correction components which maintain loop stability when feedback is applied. The collector load for VT24 is R71 with phase correcting components R103, C52 and C60.

32. This d. c. feedback pair differs from that previously described (para. 26) in that the emitter circuit of VT24 includes the diodes MR7/MR8 in place of a resistor; also, the input to the base of VT22 is shunted by

| | | |

the diodes MR9/MR10. The diodes MR7/MR8 give the correct voltage feedback to the base circuit of VT22 but from a low resistance source. The diodes MR9/MR10 are reverse-biased and so present a low shunt loading to the input while providing a low resistance path for the collector/base leakage current of VT22. In this way, the leakage current is isolated from VT22 emitter circuit and the performance of the system is preserved at the upper limit of the working temperature range.

33. The second stage d. c. feedback pair, VT26/VT27, differs from that described in para. 26 in that current feedback is not applied to VT26 (C61 bypasses R104) and VT27 is combined with VT28 to form a unity-gain amplifier. The collector load of VT26 is the tuned circuit L3/C35; L3 is tapped so as to match the collector output impedance. VT27 is an emitter follower and as such its input impedance is high. However, the addition of VT28, whose collector load is the emitter resistor of VT27, increases the input impedance of VT27 still further and so greatly reduces the loading on the tuned circuit L3/C35. R99 and C53 are phase correction components.

34. The error amplifier output at terminal M is fed via the Facility Switch and terminal P to the base of VT29. The output of the filter network (comprising C36, C37, C38, C62, R76, R77 and R105) is a direct voltage which is proportional to the error amplifier output. This voltage is fed to the bases of VT23 and VT25 and thus decreases their collector/emitter dynamic slope resistance; the transistors therefore behave as variable resistance elements. VT23, in conjunction with R62/R61, forms a variable input attenuator and VT25 effectively shunts the collector load of VT24. This system prevents serious overload of the meter and its associated circuits.

Meter Amplifier (Fig. 20)

35. The function of the meter amplifier is twofold; firstly, to provide the gain and, secondly, (in conjunction with the networks shown in fig. 2) to provide the phase change between the error amplifier output and the phase sensitive detector appropriate to the facility in use. The amplifier comprises VT30, VT31 and VT32. The operation of the circuit

is similar to that of the second stage d. c. feedback pair in the error amplifier (para. 33) except that R88 is included in the collector of VT32 so as to give a gain of approximately six between VT31 and VT32.

Unity Gain (x 1) Amplifier (Fig. 21)

36. The purpose of the x 1 amplifier is to reduce the loading between the voltage transformers T1 and T2 in the resistance and inductance bridge. Transistors VT15 and VT16 form a d. c. feedback pair feeding complementary emitter followers VT17 and VT18. The latter pair operate in Class B push-pull so as to provide the necessary power to drive transformer T2. The emitter of VT15 is connected to the 100T tap of T2 and this feedback arrangement ensures a gain of unity with an accuracy of better than 0.1%.

Guard Amplifier (Fig. 22)

37. The guard amplifier comprises the three transistors VT19, VT20 and VT21. VT19 is an emitter follower and VT20/VT21 form a two-stage feedback amplifier whose gain is within 0.2% of unity. The emitter resistance of VT19 is divided and the junction of R47/R48 is connected via C21 to the amplifier output. Thus, any change in voltage at the emitter of VT19 is accompanied by an equal (within 0.2%) change at the bottom of R47. Thus, at a. c., R47 behaves as a very high resistance which, when multiplied by the current gain of VT19, gives an input impedance of the order of 50 - 100MΩ. The overall gain of the amplifier is approximately 0.99.

38. Because the base bias resistance of VT19 (R46) is effectively in parallel with the amplifier input impedance, R49 is included and the junction R46/R49 is connected via C22 to the amplifier output. Thus R46 is neutralized at a. c., in the same manner as is R47 in the emitter circuit. The base bias resistance of VT20 is similarly neutralized.

Electrolytic Capacitance Unit

39. The Electrolytic Capacitance Unit comprises three discrete parts:

(i) the charging and timing circuit (fig. 10) comprising VT1, VT2 and VT3.

(ii) the high impedance meter circuit (fig. 10) comprising VT4, VT5, VT6 and VT7.

(iii) the leakage current circuit (fig. 11) - VT8.

40. Capacitance Initially, VT1 and VT2 are conducting whilst VT3 is cut off. When the switch PB2 (the black push button) is operated, capacitor C1 is discharged through R107 so that VT1 and VT2 are cut off and VT3 conducts. Another contact on the switch short circuits the capacitor under test to ensure that, when the switch is released, both C_u and C1 commence to charge at the same instant; this also ensures that C_u has no initial charge. C1 charges at a rate determined by R1 and RV1 until the point is reached at which VT1 and VT2 again conduct. This cuts off VT3 and so terminates the charging period of C_u. Diodes MR1, MR2 and resistor R2 form a potential divider to fix the base potential of VT3 when this transistor is conducting.

41. The charging current is determined by the range selected and is approximately E/(R5 + RV4) on range 4, E/(R4 + RV3) on range 5, E/(R3 + RV2) on range 6, where E is the voltage across capacitor C1. On ranges 4, 5 and 6, terminals N and T are connected together and so, when VT3 is cut off at the end of the charging period, C_u commences to discharge through R8 and R9. However, since the combined value of R8 and R9 is 80MΩ the discharge is very slow and is indiscernible during the few seconds required to note the meter indication.

42. Transistors VT4 and VT5 (npn) form a double emitter follower and drive the pnp emitter follower VT6. Transistor VT7 is a feedback voltage amplifier. This arrangement forms a very high impedance buffer between the voltage across the capacitor under test and the relatively low impedance of the meter circuit. The meter indication is directly proportional to this voltage, which, in turn, is inversely proportional to the unknown capacitance; thus the capacitance can be read directly from the meter reciprocal scale.

43. The base potential of VT7 is adjusted by means of potentiometer RV6 to give the precise amount of feedback necessary to prevent the meter circuit from discharging C_u too rapidly. The network containing RV5 and TH2 is the temperature-compensated series resistance for the voltmeter.

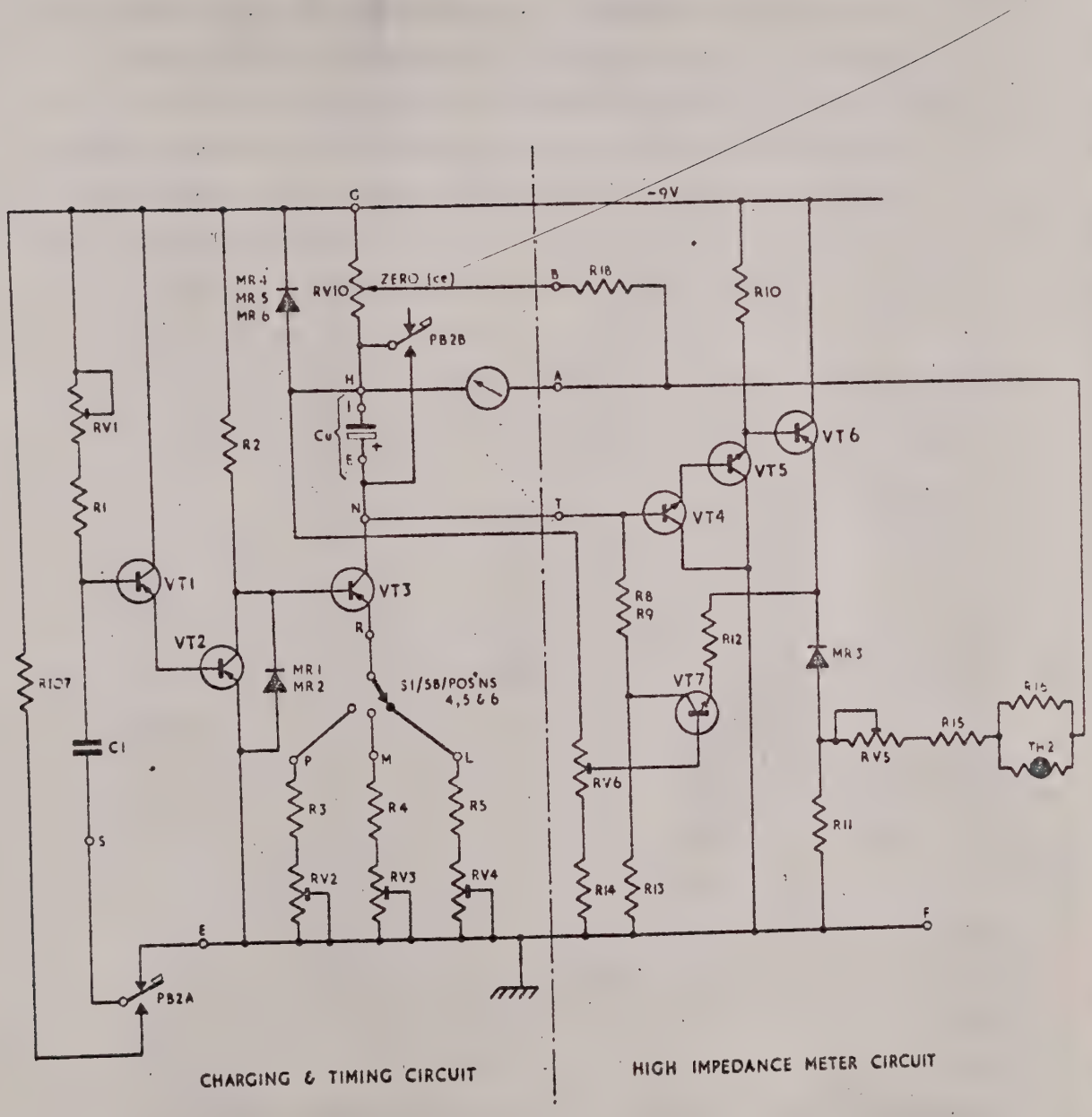


FIG. 10 ELECTROLYTIC CAPACITANCE MEASUREMENT SCHEMATIC

44. Leakage Current Selection of ranges 1, 2 or 3 on the C_e facility automatically disconnects the capacitance measuring circuits and arranges the circuit as shown in fig. 11. Transistor VT8 provides a 3V charging source for the capacitor under test, which is connected in series with the meter. Switch PB2B short circuits the meter during the charging period, thus protecting the movement against damage from the initial current surge. Meter shunts R6 and R7 extend the current measuring range.

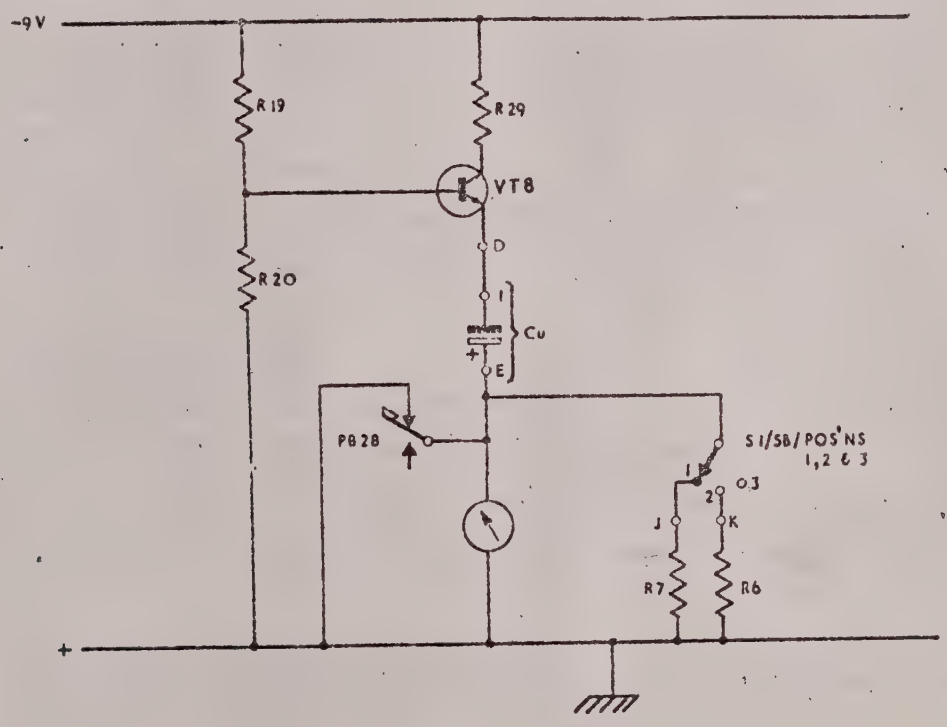


FIG. 11 ELECTROLYTIC CAPACITANCE LEAKAGE CURRENT MEASUREMENT SCHEMATIC

SETTING-UP PROCEDURES

45. The B421 is a precision instrument and it is recommended that it should be returned to the manufacturer for repair and recalibration. However, the following instructions are given for the benefit of users who have the facilities and prefer to do these operations themselves. It is stressed that they should be undertaken only by skilled personnel.

46. Test Equipment Required The following items of test equipment are required for the calibration of the instrument.

a) Multi-range meter having a sensitivity of 20 000ohms per volt, an accuracy of ±2% f. s. d. on d. c. ranges and ±4% on a. c. ranges.

b) A current meter having the following ranges:

(i) 50μA ± 2% f. s. d.

(ii) 100μA ± 2% f. s. d.

(iii) 1mA ± 2% f. s. d.

(iv) 10mA ± 2% f. s. d.

c) Decade resistance box 0 - 10kΩ ± 0.1% in steps of 1kΩ.

d) Decade capacitance box 0 - 0.1μF ± 0.1% in steps of 0.01μF.

e) Miscellaneous components as follows:

Resistor 2kΩ ± 1%; Capacitor 0.25μF ± 1% (Polystyrene)

Resistors 300Ω, 3kΩ, 30kΩ; Capacitor 10μF - all ± 5%.

47. Removal of the Case

a) Remove the Power Unit (or batteries).

b) Remove the four 2BA screws from the rear panel.

c) Lift off the rear panel complete with its surround.

d) The centre portion of the case is now free and can also be lifted off.

48. Calibration Procedure

a) Check the supply voltage and f. s. d. calibration as instructed in the Operating Instructions.

b) Connect the decade capacitance box, set to 0.1μF, to the Unknown terminals and set the Range switch to 3. Set the Decade switch to OUT and the Facility switch to C. The meter should indicate f. s. d. (i. e. 10 x 10nF = 100nF = 0.1μF).

c) Set the Range switch to 2 and the Decade switch to 0.

d) The meter should indicate f. s. d. If it does not, capacitance may be added in parallel with C57 (on the Standards Board in position marked C57A - AIC) at the rate of 100pF per 1% over f. s. d. Polystyrene capacitors of 1% tolerance should be used. The necessity for this step is unlikely, but if it is found that more than 200pF is required, the instrument should be returned to the manufacturers.

e) Set the Range switch to 3 and the Decade switch to 10.

f) The meter should indicate zero. If it does not, adjust C55 on the Standards Board until it does.

g) Set the Decade switch to 9 and press the minor term button. The meter should indicate zero. If it does not, adjust L3 on the Error and Meter Amplifier Board until it does (the adjustment is made through the hole in the top of the metal screen).

h) Set the Decade switch to OUT. Check the meter linearity by stepping the decade capacitance box from 0.1μF to 0.01μF.

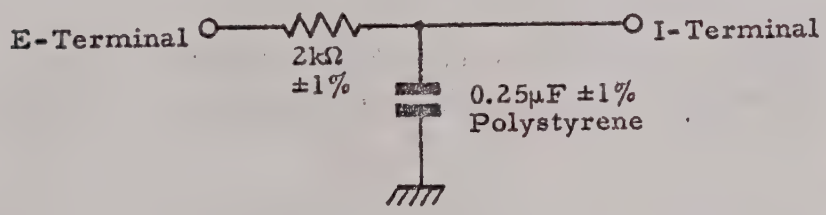
i) Check the Decade switch by stepping the decade capacitance box from 0.01 to 0.1μF following, step by step, with the Decade switch.

j) Set the Decade switch to 0 and connect a 10kΩ ± 0.1% resistor (the decade resistance box) in parallel with the decade capacitance box.

k) Press the minor term button. The meter should indicate 1 on the green reciprocal scale. If it does not, adjust RV9 on the Standards Board until it does.

l) Disconnect all components from the Unknown terminals, set the Range switch to 7 and the Decade switch to 0. The meter should indicate zero ± 1 scale division.

m) Connect the synthetic inductance circuit shown in the sketch to the



Synthetic Inductance

Unknown terminals. Set the Facility switch to L and the Range switch to 5. The meter should indicate f. s. d. If it does not, adjust RV8 on the Standards Board until it does.

n) Disconnect the synthetic inductance and connect the decade resistance box, set to 10kΩ, to the Unknown terminals. The meter should indicate zero. If it does not, adjust RV7 on the Standards Board until it does.

o) Press the minor term button and check that the meter indicates 10 on the black scale. Repeat operations m) and n).

p) Short circuit the two Unknown terminals. The meter should indicate zero ±1 division on all ranges. Remove the short circuit and check that the meter indication is greater than f. s. d. on all ranges.

q) Connect the decade resistance box to the Unknown terminals. Set the Facility switch to R, the Range switch to 4 and the Decade switch to OUT.

r) Step the decade resistance box from 0 to 10kΩ in steps of 1kΩ and check the linearity of the meter.

s) Check the Decade switch by setting it to each position in sequence, adjusting the decade resistance box as appropriate from 0 to 10kΩ in steps of 1kΩ.

t) Remove the decade resistance box, set the Decade switch to 0 and short circuit the Unknown terminals. The meter should indicate zero ± 1 division on all ranges. Remove the short circuit and check that the meter indication is greater than f. s. d. on all ranges.

u) Set the Facility switch to Ce and the Range switch to 1. Connect a 0 - 10mA meter in series with a 3000Ω resistor across the Unknown terminals.

v) Whilst pressing the black push button, check that the external meter and the instrument meter indicate f. s. d. ± 5% and that the meter indications correspond to within 5%.

w) Set the Range switch to 2 and change the external meter to 1mA f. s. d. in series with a 3kΩ resistor. Whilst pressing the black push button, check that the meters indicate f. s. d. as in operation v).

x) Set the Range switch to 3 and change the external meter to 100μA f. s. d. in series with a 30kΩ resistor. Whilst pressing the black push button, check that the meters indicate as in operation v).

y) Set the Range switch to 4 and change the external meter to 50μA f. s. d. with no series resistor. Press and release the black push button. The external meter should indicate 10μA for approximately 1 second; if it does not, adjust RV4 on the Electrolytic Board until it does.

Note: In this and the two following operations, it may be necessary to press the black push button more than once to complete the adjustment.

z) Set the Range switch to 5 and change the external meter to 100μA f. s. d. with no series resistor. Press and release the black push

button. The external meter should indicate 100μA for approximately 1 second; if it does not, adjust RV3 on the Electrolytic Board until it does.

aa) Set the Range switch to 6 and change the external meter to 1mA f. s. d. with no series resistor. Press and release the black push button. The external meter should indicate 1mA for approximately 1 second; if it does not, adjust RV2 on the Electrolytic Board until it does.

bb) Set the Calibrate switch to Zero Ce and the Range switch to 4. Adjust the Zero (Ce) potentiometer until the meter indicates zero.

cc) Connect a capacitor of 10μF ± 5% to the Unknown terminals. Press and release the black push button. The meter should indicate a steady f. s. d.; if it does not, adjust RV5 on the Electrolytic Board. If RV5 has insufficient range of control, make a small adjustment to RV1 and repeat the test until the correct result can be obtained using RV5.

dd) Check the setting of the Zero (Ce) control and then repeat operation cc). If the meter indication drifts without allowing a reasonable reading time, adjust RV6 on the Electrolytic Board to correct the drift.

ee) Repeat operations bb), cc) and dd).

Typical D. C. Voltages

49. The following tables give typical d. c. voltages at the specified points. They should be measured with an instrument having a sensitivity of not less than 20, 000Ω/volt (e. g. Avo Model 8).

OSCILLATOR

Point/Junction	Voltage	Voltage	Voltage
VT11 Emitter/R26	0.35		
VT11 Collector/R27	1.75		
VT12 Emitter/R30	1.7		
Junction R30/R31/R25	0.5		
Junction R31/R32	0.35		

Cont.

Oscillator cont.

Point/Junction	Voltage	Voltage	Voltage
Collector VT12/L1	9.0		
Emitter VT13/R34/C9)) Emitter VT14/R35/C10))	0.2		
Collectors of VT13/VT14/R33	8.5		

ERROR AMPLIFIER

Point/Junction	Voltage	Voltage	Voltage
Base VT22/MR9 and MR10/R67/C26	0.25		
Emitter VT22/R101	0.15		
Collector VT22/Base VT24/R68	1.95		
Emitter VT24/C31/MR7	1.85		
MR8/R70/R67	0.3		
Collector VT24/R71/C52/C60/C30	4.9		
Base VT26/R73/C30/MR11 & MR12	0.85		
Emitter VT26/R104/C61	0.75		
Collector VT26/L3	4.8		
R75/C34/R74	4.8		
Emitter VT27/R97/R99	4.7		
Collector VT27/Base VT28/R78	8.75		
Collector VT28/R97/C40/R80	4.7		
R80/R79/C39/R73	0.85		

x1 AMPLIFIER

Point/Junction	Voltage	Voltage	Voltage
R37/C12	8.5		
VT15 Base/R38/C11	0.15		

Cont.

x 1 Amplifier cont.

Point/Junction	Voltage	Voltage	Voltage
R39/C14/L2/C15	5.05		
Emitter VT16/R41	5.00		
R41/R40/R42/C16	0.2		
Emitter VT18/Emitter VT17/C17	5.0		

GUARD AMPLIFIER

Point/Junction	Voltage	Voltage	Voltage
Collector VT19/R49/R46/C22	7.0		
Emitter VT19/C19/R47	4.0		
R47/C21/R48	2.0		
R45/R51/R44	5.25		
Emitter VT20/Collector VT21/ C20/R53/C21/C22/C23	5.0		
Collector VT20/Base VT21/C51/R52	8.5		

METER AMPLIFIER

Point/Junction	Voltage	Voltage	Voltage
Base VT30/C43/R84/MR13 and MR14	0.85		
Emitter VT30/R85/C45	0.7		
Collector VT30/R86/C44/ Base VT31	1.75		
Emitter VT31/R88/C54/R89	1.6		
R89/R90/C46	0.95		
Collector VT31/Base VT32/R87	8.75		
Collector VT32/C47/R88/C54	5.0		

ELECTROLYTIC CAPACITANCE UNIT

Point/Junction	Voltage	Voltage	Voltage
Base VT1/R1/C1 shorted to ground chassis. S4 at C_e zero			
Collector VT2/MR1/Base VT3	1.3		
Emitter VT6/MR3/R12	7.0		
MR3/R11/RV5	6.2		
Emitter VT7/R12	4.8		
Collector VT7/R13	4.0		
MR6/ RV6 - point H	6.5		
R18/R16/TH2 - point A	6.5		
R19/R20/Base VT8	3.0		

LIST OF COMPONENTS

When ordering spare parts, please quote the Instrument Type and Serial Numbers, and the circuit reference and value of the required component.

t. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
R1	1.2M	2	1W	Electrosil Type N 2S
R2	5.6K	10	1/4W	RC7-K
R3	620	2	1/4W	Electrosil Type NJ6S
R4	6.8K	2	1/4W	Electrosil Type NJ6S
R5	68K	2	1/4W	Electrosil Type NJ6S
R6	130	2	1/4W	Radio Resistor 2HS2
R7	12	2	1/4W	Radio Resistor 2HS2
R8	40M	20		Erie Type 9
R9	40M	20		Erie Type 9
R10	39K	10	1/4W	RC7-K
R11	18K	10	1/4W	RC7-K
R12	18K	10	1/4W	RC7-K
R13	39K	10	1/4W	RC7-K
R14	4.7K	10	1/4W	RC7-K
R15	10K	2	1/4W	Electrosil Type NJ6S
R16	8.2K	10	1/4W	RC7-K
R17	100K	2	1/4W	Electrosil Type NJ6S
R18	100K	10	1/4W	RC7-K
R19	5.6K	5	1/4W	RC7-K
R20	2.7K	10	1/4W	RC7-K
R21	2.7K	10	1/4W	RC7-K
R22	2.2K	10	1/4W	RC7-K
R23	2.2K	10	1/4W	RC7-K
R24	2.7K	10	1/4W	RC7-K
R25	3.3K	10	1/4W	RC7-K
R26	1K	10	1/4W	RC7-K
R27	18K	10	1/4W	RC7-K
R28	1K	10	1/4W	RC7-K
R29	390	10	1/4W	RC7-K
R30	1K	10	1/4W	Morgan Type S
R31	120	10	1/4W	RC7-K

Cct. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
R32	330	10	1/4W	RC7-K
R33	56	10	1/4W	RC7-K
R34	47	10	1/4W	RC7-K
R35	47	10	1/4W	RC7-K
R36	470	10	1/4W	RC7-K
R37	180	10	1/4W	RC7-K
R38	4.7K	10	1/4W	RC7-K
R39	2.2K	10	1/4W	RC7-K
R40	2.7K	10	1/4W	RC7-K
R41	4.7K	10	1/4W	RC7-K
R42	220	10	1/4W	RC7-K
R43	22	10	1/4W	RC7-K
R44	22K	10	1/4W	RC7-K
R45	22K	10	1/4W	RC7-K
R46	1.2M	10	1/4W	RC7-K
R47	22K	10	1/4W	RC7-K
R48	22K	10	1/4W	RC7-K
R49	22K	10	1/4W	RC7-K
R50	22K	10	1/4W	RC7-K
R51	22K	10	1/4W	RC7-K
R52	1.2K	10	1/4W	RC7-K
R53	4.7K	10	1/4W	RC7-K
R54	4.7K	10	1/4W	RC7-K
R55	200K	5	1/2W	Welwyn F20
R56	20K	5	1/2W	Welwyn F20
R57	2K	1	1/4W	Electrosil NJ65
R58	200	5	1/4W	Welwyn F20
R59	20	5	1/2W	Welwyn F20
R60	2	5	2.6W	Welwyn 10W/19328-10419
R61	2.2K	10	1/4W	RC7-K
R62	2.7K	10	1/4W	RC7-K
R63	470	10	1/4W	RC7-K
R64	150	10	1/4W	RC7-K
R65	15K	10	1/4W	RC7-K

Cct. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
R66	560	10	1/4W	RC7-K
R67	1K	10	1/10W	Morganite Type X
R68	4.7K	10	1/4W	RC7-K
R69	NOT USED			
R70	270	10	1/4W	RC7-K
R71	2.7K	10	1/4W	RC7-K
R72	47	10	1/4W	RC7-K
R73	4.7K	10	1/4W	RC7-K
R74	15	10	1/4W	RC7-K
R75	4.7K	10	1/4W	RC7-K
R76	1.5K	10	1/4W	RC7-K
R77	1.5K	10	1/4W	RC7-K
R78	1K	10	1/4W	RC7-K
R79	270	10	1/4W	RC7-K
R80	1K	10	1/4W	RC7-K
R81	6.8K	10	1/4W	RC7-K
R82	100	10	1/4W	RC7-K
R83	100	10	1/4W	RC7-K
R84	8.2K	10	1/4W	RC7-K
R85	1K	10	1/4W	RC7-K
R86	10K	10	1/4W	RC7-K
R87	680	10	1/4W	RC7-K
R88	1K	10	1/4W	RC7-K
R89	180	10	1/4W	RC7-K
R90	220	10	1/4W	RC7-K
R91	6.8K	2	1/8W	RC3-L
R92	5.6K	2	1/8W	RC3-L
R93	24K	2	1/8W	RC3-L
R94	18K	2	1/8W	RC3-L
R95	91	5	1/16W	RC7-P
R96	10	5	1/16W	RC7-P
R97	220	10	1/4W	RC7-K
*R98	10020	0.1	1/4W	Alma MA 1/4
R99	82	10	1/4W	RC7-K

Cct. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
R100	1K	10	1/4W	RC7-K
R101	100	10	1/4W	RC7-K
R102	560	10	1/4W	RC7-K
R103	560	10	1/4W	RC7-K
R104	1K	10	1/4W	RC7-K
R105	180	10	1/4W	RC7-K
R106	3.9K	10	1/10W	Morganite Type X
R107	10K	10	1/4W	RC7-K
*R108	22	10	1/4W	RC7-K
R109	100	10	1/4W	RC7-K
R110	NOT USED			
R111	22	10	1/4W	Morgan 'S'
RV1	250K	20	1/4W	Plessey G Mk 5
RV2	100	10	1/4W	Plessey G Mk 5
RV3	1K	20	1/4W	Plessey G Mk 5
RV4	5K	20	1/4W	Plessey G Mk 5
RV5	5K	20	1/4W	Plessey G Mk 5
RV6	2.5K	20	1/4W	Plessey G Mk 5
*RV7	1K	20	1/4W	Plessey G Mk 5
*RV8	2.5K	20	1/4W	Plessey G Mk 5
*RV9	5K	20	1/4W	Plessey G Mk 5
RV10	100K	20	1/4W	Morganite BJ
RV11	2.5K	20	1/4W	Morganite BJ
C1	2	10	150V	Salford PFT
C2	400	-10 +50	10V	Mullard C437AR D400
C3	64	-10 +50	10V	Mullard C426AR D64
C4	1500p	10	150V	Salford PFT
C5	0.1	2	125V	Wima Tropyfol F
C6	64	-10 +50	10V	Mullard C426AR D64
C7	64	-10 +50	10V	Mullard C426AR D64
C8	3000p	10	150V	Salford PFT

Cct. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
C9	64	-10 +50	10V	Mullard C426AR C64
C10	64	-10 +50	10V	Mullard C426AR D64
C11	16	-10 +50	10V	Mullard C426AR D16
C12	400	-10 +50	10V	Mullard C437AR D400
C13	64	-10 +50	10V	Mullard C426AR D64
C14	400	-10 +50	10V	Mullard C437AR D400
C15	0.1	2	125V	Wima Tropyfol F
C16	64	-10 +50	10V	Mullard C426AR D64
C17	400	-10 +50	10V	Mullard C437AR D400
C18	6.4	-10 +50	25V	Mullard C426AR F6.4
C19	6.4	-10 +50	25V	Mullard C426AR F6.4
C20	6.4	-10 +50	25V	Mullard C426AR F6.4
C21	6.4	-10 +50	25V	Mullard C426AR F6.4
C22	6.4	-10 +50	25V	Mullard C426AR F6.4
C23	6.4	-10 +50	25V	Mullard C426AR F6.4
C24	3000p	10	150V	Salford PFT
C25	6.4	-10 +50	25V	Mullard C426AR F6.4
C26	6.4	-10 +50	25V	Mullard C426AR F6.4
C27	400	-10 +50	10V	Mullard C437CE D400
C28	25000p	10	150V	Salford PFT
C29	64	-10 +50	10V	Mullard C426CB D64
C30	6.4	-10 +50	25V	Mullard C426AR F6.4

Cct. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
C31	400	-10 +50	10V	Mullard C437CE D400
C32	16	-10 +50	10V	Mullard C426AR D16
C33	400	-10 +50	10V	Mullard C437CB D400
C34	400	-10 +50	10V	Mullard C437CB D400
C35	0.1	1	150V	Salford PFT
C36	64	-10 +50	10V	Mullard C426CB D64
C37	64	-10 +50	10V	Mullard C426CB D64
C38	200	-10 +50	10V	Mullard C426CB D200
C39	64	-10 +50	10V	Mullard C426CB D64
C40	400	-10 +50	10V	Mullard C437CB D400
C41	6.4	-10 +50	25V	Mullard C426AR F6.4
C42	400	-10 +50	10V	Mullard C437CB D400
C43	16	-10 +50	10V	Mullard C426AR D16
C44	3000p	10	150V	Salford PFT
C45	64	-10 +50	10V	Mullard C426CB D64
C46	400	-10 +50	10V	Mullard C437CB D400
C47	64	-10 +50	10V	Mullard C426CB D64
C48	20000p	10	150V	Salford PFT
C49	10000p	10	150V	Salford PFT
C50	5000p	10	150V	Salford PFT
C51	30000p	10	150V	Salford PFT
C52	3000p	10	150V	Salford PFT
C53	30000p	10	150V	Salford PFT
C54	3000p	10	150V	Salford PFT

Cct. Ref.	Value	Tol. ±%	Rating	Manufacturer or I. S. Style
*C55	2-30p	-0 +20	150V	Oxley A7/30 CVA7C
*C56	10000p	+0 -1	200V	S & M Silver Star C33E
*C56A	50p	5	125V	Polystyrene Dielectric
	30p	5	125V	Value selected on test
*C57	9820p	1	125V	STC 455 LWA 104CP
*C57A	100p	5	125V	Polystyrene Dielectric
	200p	5	125V	Value selected on test
	250p/150p	5	125V	" "
C58	10000p	10	150V	Salford PFT
C59	10000p	10	150V	Salford PFT
C60	30000p	10	150V	Salford PFT
C61	400	-10 +50	10V	Mullard C437CB D400
C62	200	-10 +50	10V	Mullard C426CB D200
C63	0.47	10	150V	Salford PFT
C64	100p	±3p	125V	Salford Type PF
C65	.02	-25 +50	30V	Radio Spares Ltd.
C66	16		10V	Mullard C426AR D16
C67	82p	5	150V	G. E. C. Type PF82

Cct. Ref.	Type	Manufacturer or I. S. Style
L1	Inductor	Wayne Kerr Dwg. D12576
L2	Inductor	" " " D12577
L3	Inductor	" " " D12577
MR1-MR6	1S920	Texas (CV7332)
MR7, MR8	1S920	Texas (CV7332)
MR9-MR14	OA91	Mullard (CV7130)
PB1	White Miniature Push Button	AB Metals IVS/063/2
PB2	Black " " " " "	IVS/0264/2

Cct. Ref	Type	Manufacturer or I. S. Style
VT1	OC202	Mullard (CV7342)
VT2	ASY66	STC (CV7185)
VT3	OC200	Mullard (CV7341)
VT4	2S501	Texas (CV7492)
VT5	2S702	Texas (CV7372)
VT6	OC202	Mullard (CV7342)
VT7	2N1304	Texas (CV7349)
VT8	2G374	Texas (CV7439)
VT9	ASY66	STC (CV7185)
VT10	ASY66	STC (CV7185)
VT11	2G374	Texas (CV7439)
VT12	2G374	Texas (CV7439)
VT13	ACY19	Mullard (CV7437)
VT14	ACY19	Mullard (CV7437)
VT15	2G374	Texas (CV7439)
VT16	2G374	Texas (CV7439)
VT17	2N1304	Texas (CV7349)
VT18	2G374	Texas (CV7439)
VT19	OC202	Mullard (CV7342)
VT20	2G374	Texas (CV7439)
VT21	2N1304	Texas (CV7349)
VT22	2G374	Texas (CV7439)
VT23	OC200	Mullard (CV7341)
VT24	2G374	Texas (CV7439)
VT25	OC200	Mullard (CV7341)
VT26	2G374	Texas (CV7439)
VT27	2G374	Texas (CV7439)
VT28	2N1304	Texas (CV7349)
VT29	2G374	Texas (CV7439)
VT30	2G374	Texas (CV7439)
VT31	2G374	Texas (CV7439)
VT32	2N1304	Texas (CV7349)

Cct Ref.	Description	Manufacturer or W.K. Ref
S1	Range Switch	W.K. Dwg. D12787
S2	Facility Switch	W.K. Dwg. D12788
S3	Decade Switch	W.K. Dwg. D12789
S4	Calibrate Switch	W.K. Dwg. D12597
T1	Transformer	W.K. Dwg. D12578/1/2
T2	Voltage Transformer	W.K. Dwg. D12579
T3	Current Transformer	W.K. Dwg. D12579
M1	Meter Hermetically sealed Accuracy ±2% F.S.D. Int. Res. 1200Ω scaled 0-10.	Ferranti RCL231 Scale to Dwg. D11668
TH1	Thermistor R24	STC
TH2	Thermistor G14	STC

* Component affecting calibration.

APPENDIX I

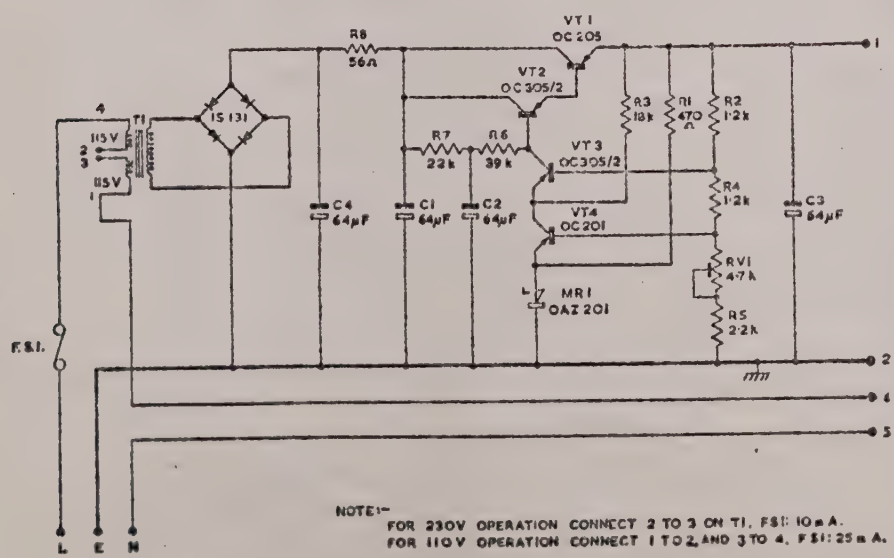
POWER SUPPLY UNIT PS109/2

Power Supply Unit PS109/2 is fitted to the B421 to provide for operation from a. c. supplies of 110V or 200-250V, 50-60Hz. The Unit produces a stabilised d. c. output of 9 volts. Before connecting the PS109/2 to the a. c. supply, check that the primary taps on T1 are connected as follows:

230-volt supply	110-volt supply
2-3 linked (no other connection)	1-2 linked, to neutral
1 live	3-4 linked, to live
4 neutral	

In addition to the two line connections, as above, the green wire of the power cable must be connected to a ground terminal. The fuse (FS1) should be 25mA for 110-volt operation or 10mA for 230-volt operation.

One lead to the primary is switched by the 'Facility' switch. A bridge rectifier is energised from the secondary of T1 and a capacitance-input R-C smoothing circuit is employed. The emitter of VT4 is held at a reference potential by zener diode MR1. Any variation in the h. t. line potential causes a corresponding change in the potential of VT4 base (the mean operating point being established by adjustment of the preset control RV1). The change is amplified by VT4 and VT3 and applied, via the emitter follower VT2, to the base of the series regulator transistor VT1. The net effect of the circuit is to minimise any fluctuations in the h. t. potential.



PS109/2
Circuit Diagram

NOTE:-
FOR 230V OPERATION CONNECT 2 TO 3 ON T1, FS1: 10m A.
FOR 110V OPERATION CONNECT 1 TO 2, AND 3 TO 4, FS1: 25m A.

APPENDIX II

VOLTAGE APPLIED TO THE UNKNOWN

Because both the configuration of the bridge and the gain of the error amplifier are changed when switching to the various facilities, the voltage applied to the unknown varies according to the facility selected, the decade setting and the meter indication.

Capacitance

When measuring capacitance, the oscillator output is connected directly to the secondary of T2 (see Fig.13) and the error amplifier feedback is applied to the current transformer T3; thus the voltage applied to the unknown depends only on the setting of the Range switch.

Range	Applied Voltage
7	23.5V rms
5, 6	2.35V rms
3, 4	235mV rms
1, 2	23.5mV rms

Inductance

On the inductance ranges the oscillator output is fed to a standard resistor and the error amplifier output is fed back to the voltage transformer T2 (see Fig.15). Thus, the voltage applied to the unknown is a function both of the Range in use and of the meter indication.

Range	Applied Voltage when Meter indicates 1 on black scale	
7	150mV rms	For other values, multiply the voltage appropriate to the range in use by the meter indication.
5, 6	15mV rms	
3, 4	1.5mV rms	
1, 2	150μV rms	

Example: The meter (black scale) indicates 6 on Range 5.

L = 600mH.

Applied Voltage = 6 x 15 = 90mV

Resistance

The bridge arrangement for resistance measurements (see Fig.14) is similar to that for inductance except that the error amplifier output is fed to T2 via the decade winding. The voltage applied to the unknown is now a function of the Range setting, the meter indication and the Decade setting. In the Table below, the voltage quoted for each range is a key figure (v) and is the voltage applied to the unknown for a meter indication of 1(black scale) when the Decade is set to OUT. The applied voltage (V) for any resistance measurement can be calculated from the formulae given below the table.

Range	v
7	230mV rms
5, 6	23mV rms
3, 4	2.3mV rms
1, 2	230μV rms

Decade OUT

Applied Voltage V = v x meter indication

Decade in use

V = (10v x Decade setting) + (v x meter indication)

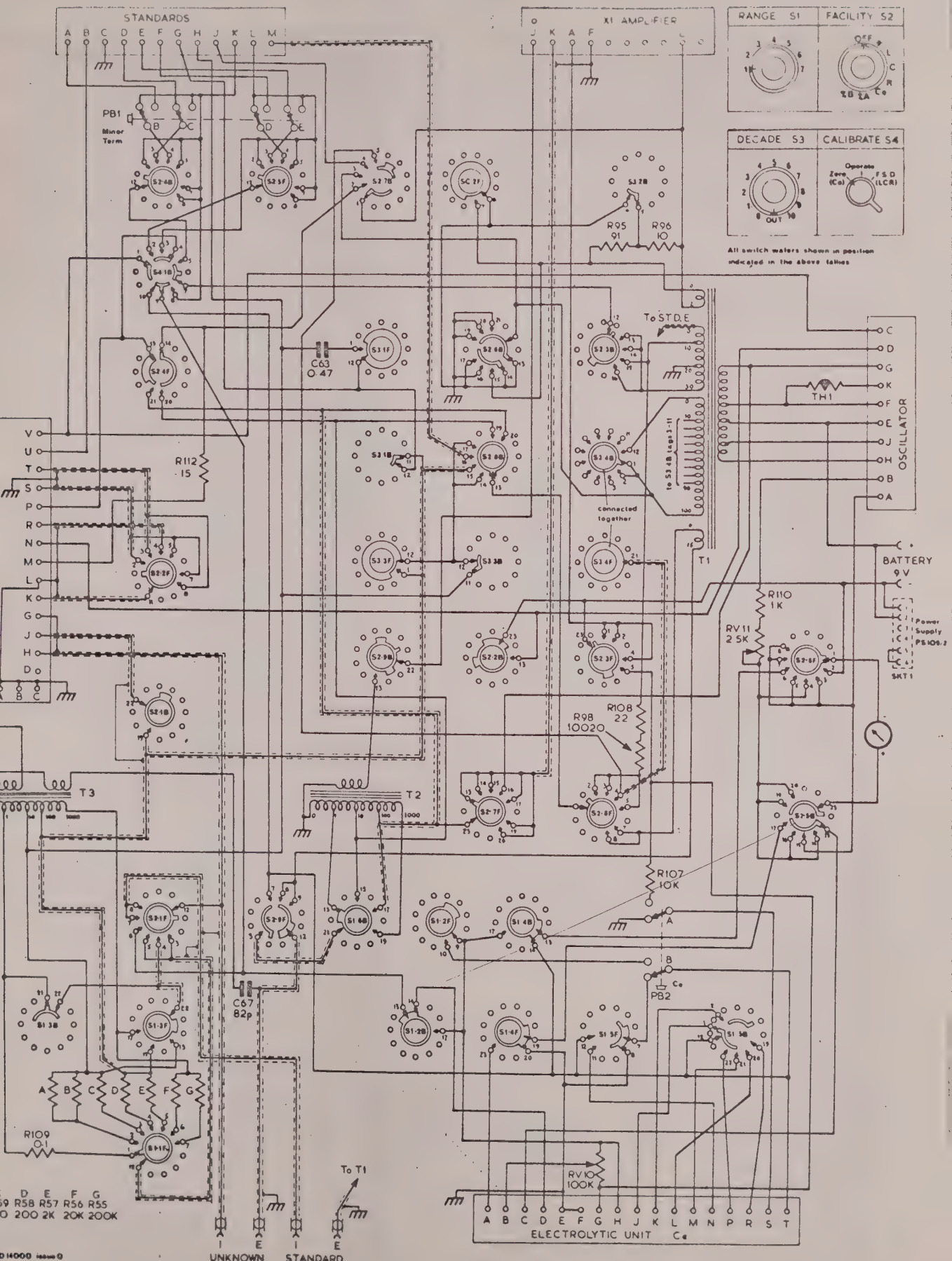
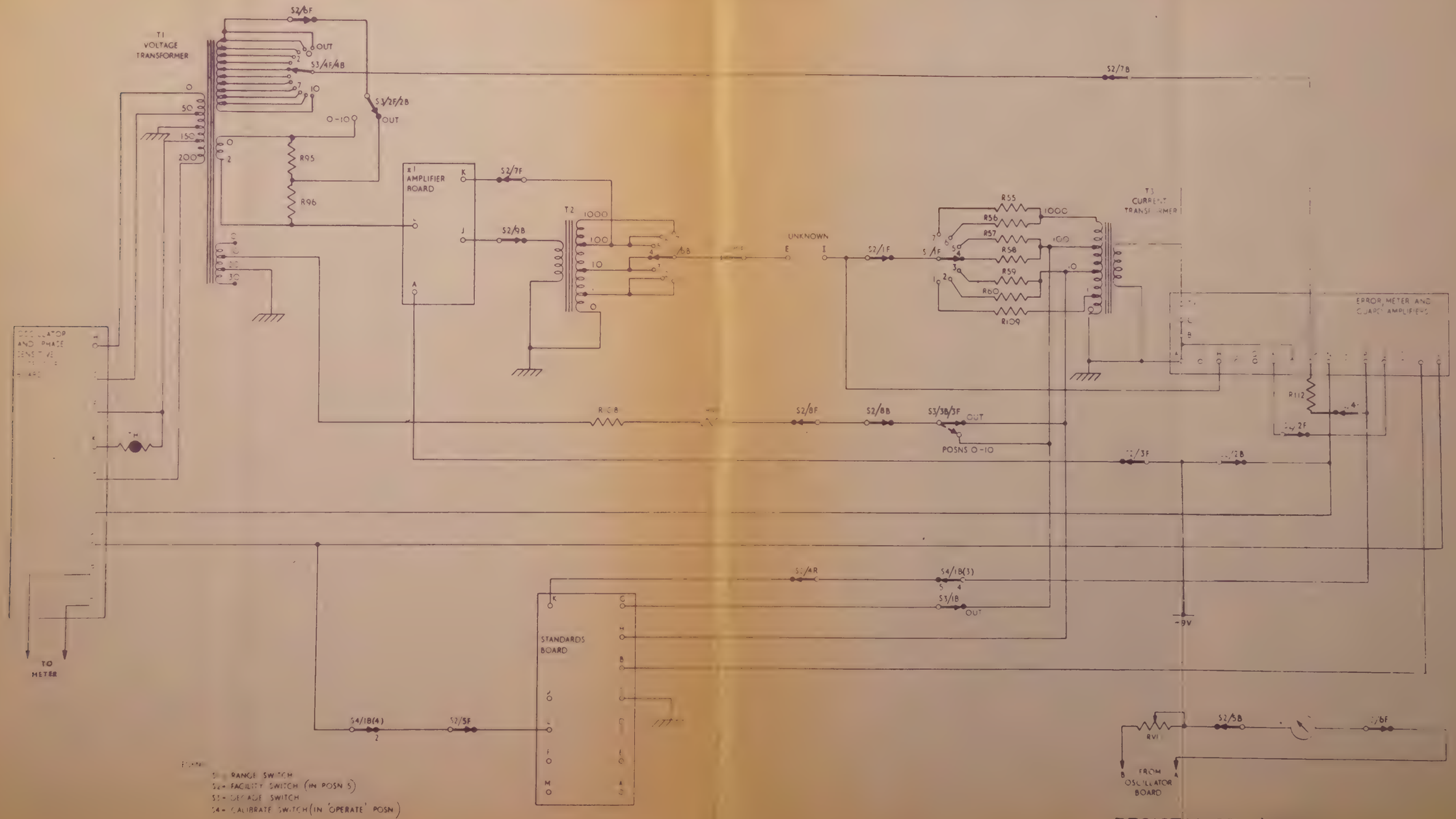


FIG 12 B421 INTERCONNECTION DIAGRAM

| | | |

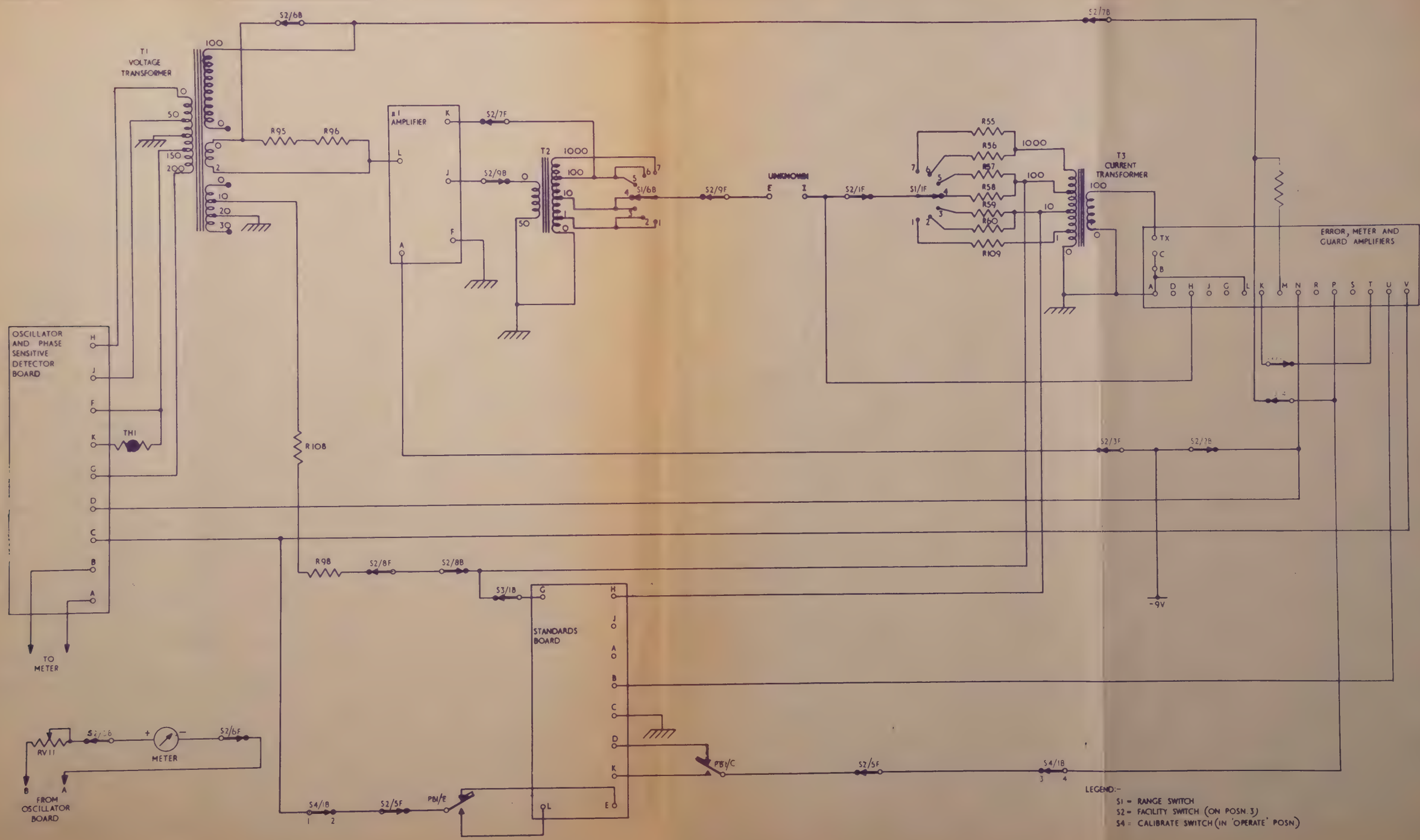
R	95 96	108	53 56 57 58 59 60 109	112
C				
MISC.	TH1 T1 T	T2	T3 RV11	



RESISTANCE BRIDGE
INTERCONNECTIONS

FIG 14

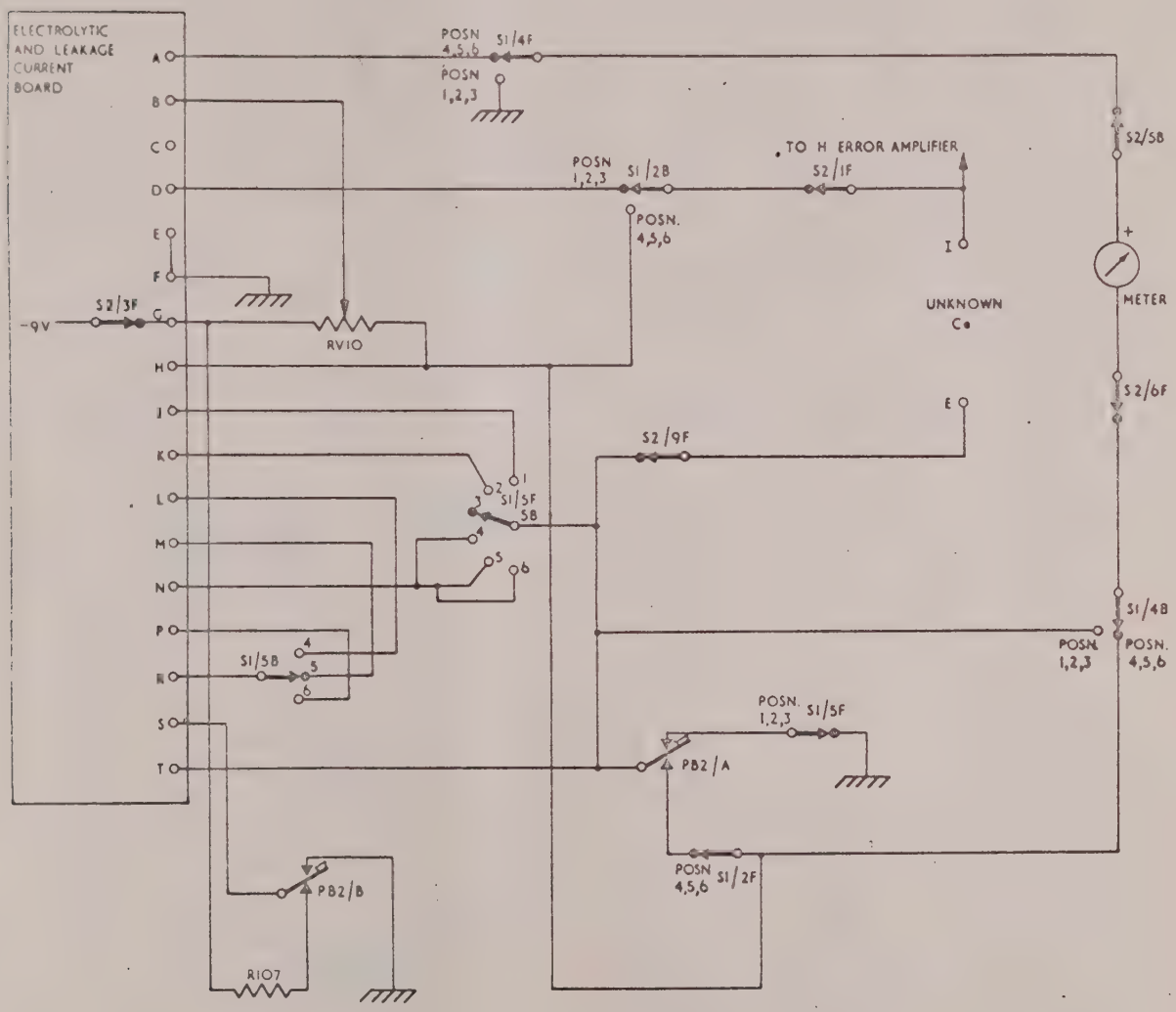
R	95,96,98,108		55,56,57,58,59,60,109	112
C				
MISC	RV11	TH1, T1	T2	T3



INDUCTANCE BRIDGE
INTERCONNECTIONS

FIG.15.

-	·07
C	
MISC	RV10



S1 = RANGE SWITCH (POSN.4,5 OR 6 FOR Cx; POSN.1,2 OR 3 FOR LEAKAGE)
S2 = FACILITY SWITCH (ON POSN 6)

ALL SWITCHES OPEN ON ANY POSITION OTHER THAN THOSE INDICATED.

ELECTROLYTIC CAPACITANCE AND LEAKAGE CURRENT INTERCONNECTIONS

FIG 16

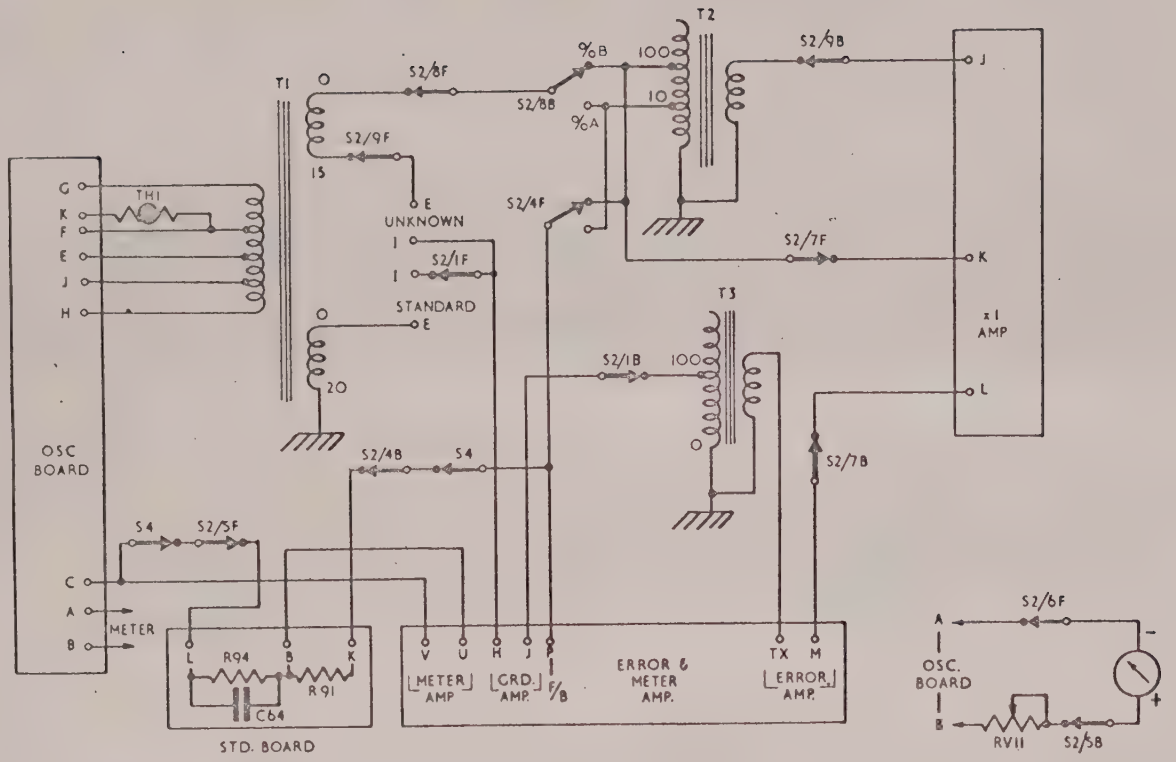
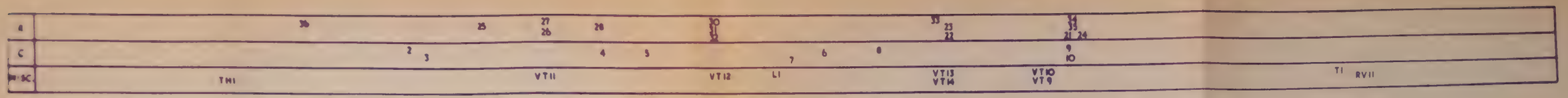
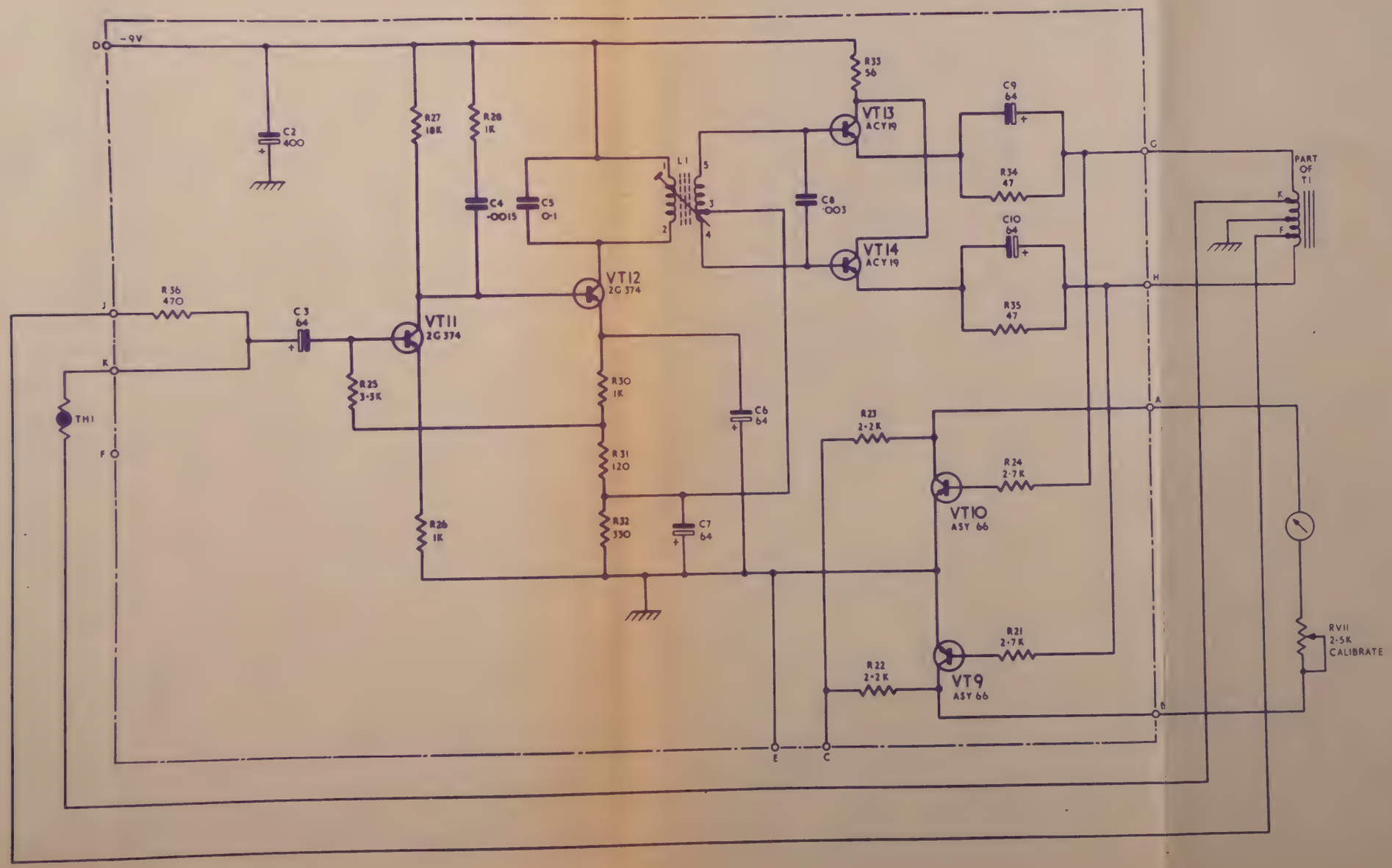


FIG.17 COMPARATOR BRIDGE — INTERCONNECTION DIAGRAM





BRIDGE OSCILLATOR & PHASE-SENSITIVE DETECTOR

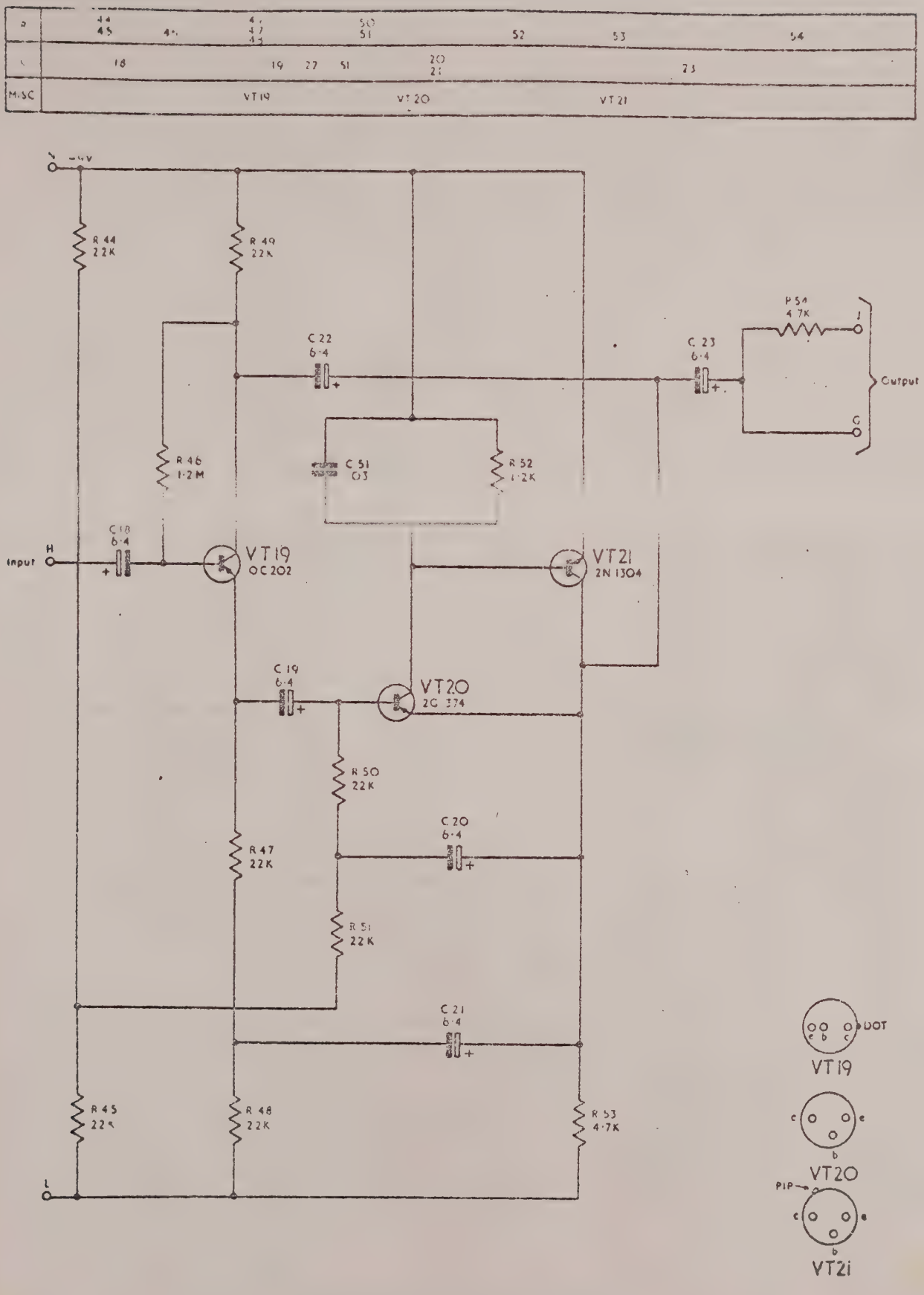
CIRCUIT DIAGRAM

FIG. 18

| | | |

| | | |

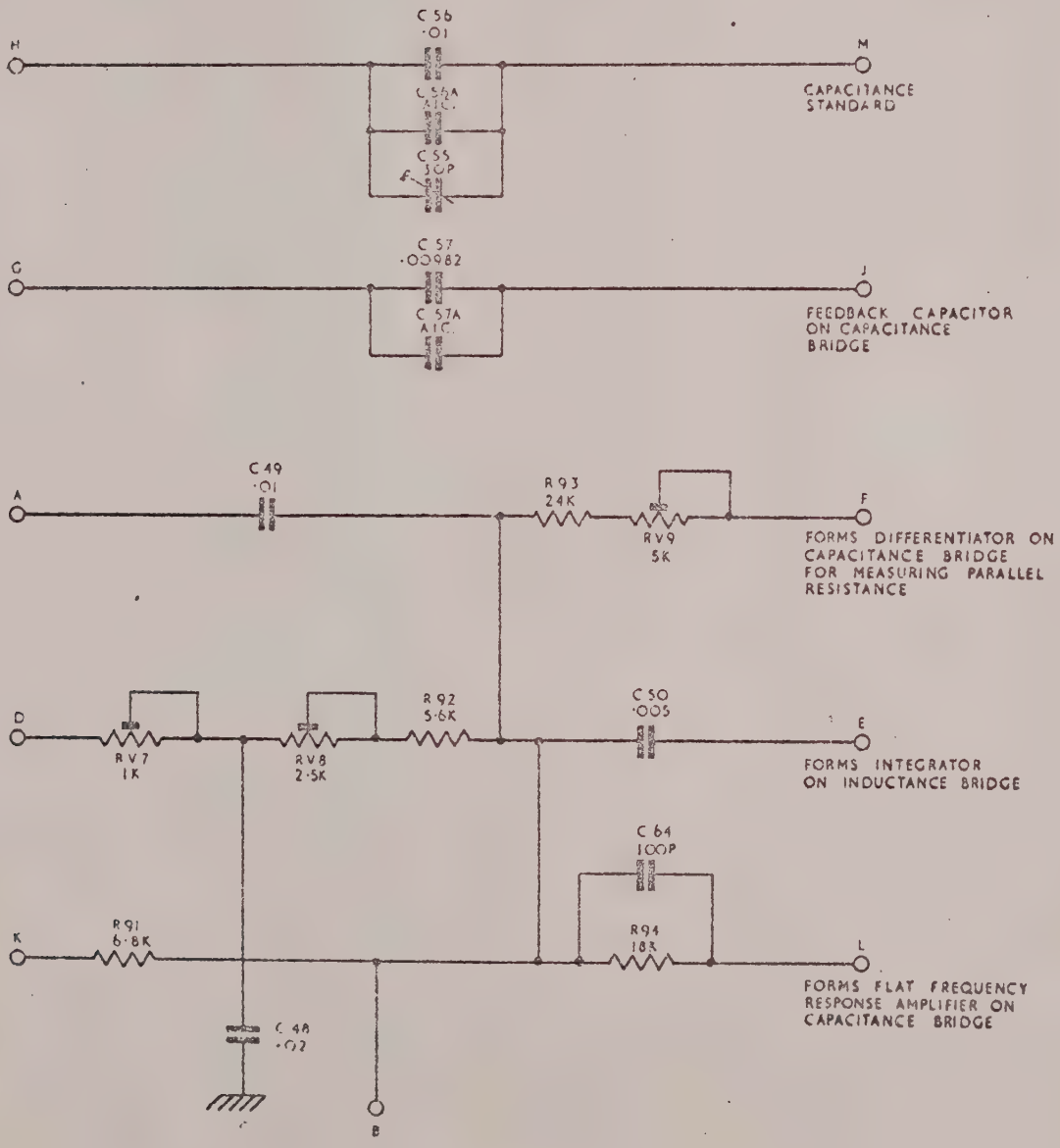
| | | |



GUARD AMPLIFIER
CIRCUIT DIAGRAM

FIG. 22

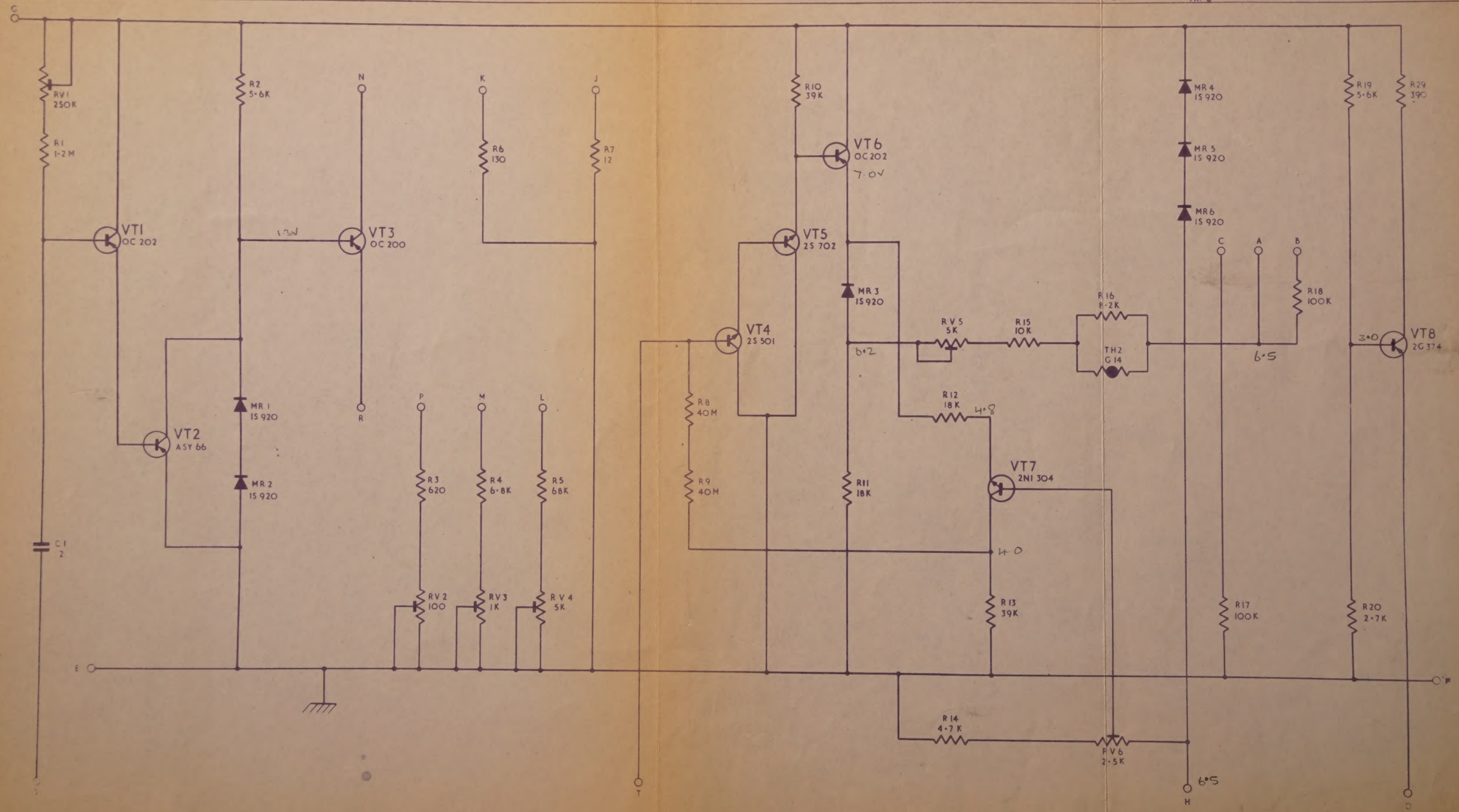
R	91		92	93	94
C		49 48	56 57 56A 57A 52		50 64
MISC	RV7	RV8			RV9

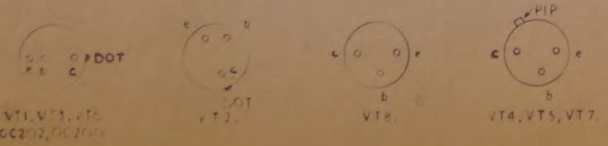


STANDARDS BOARD
CIRCUIT DIAGRAM

FIG. 23

P	1		2		3	6 4	5	7	8 9	10	11	12 14	13	15	16	17	18	19 20	21
C	1																		
MISC	RV1	VT1	VT2	MR1 MR2	VT3	RV2	RV3	RV4	VT4	VT5	VT6 MR3	RV5	VT7	TH2 RV6	MR4 MR5 MR6				VT8





ELECTROLYTIC BOARD
CIRCUIT DIAGRAM

FIG 24

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